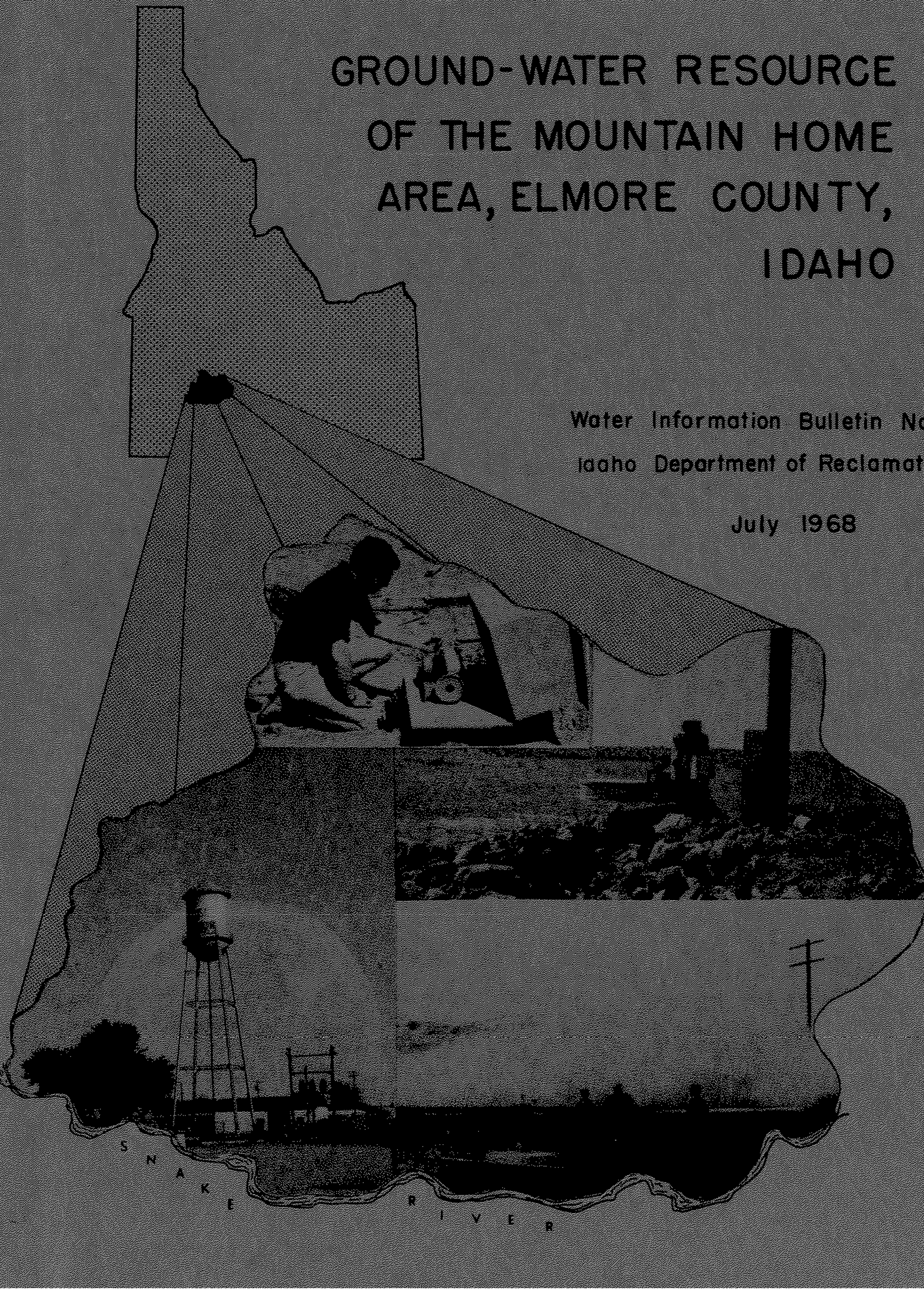
GROUND-WATER RESOURCE OF THE MOUNTAIN HOME AREA, ELMORE COUNTY, IDAHO



Water Information Bulletin No. 4

Idaho Department of Reclamation

July 1968

WATER INFORMATION BULLETIN NO. 4

GROUND-WATER RESOURCE OF THE MOUNTAIN HOME AREA, ELMORE COUNTY, IDAHO

by

Dale R. Ralston Hydrologist

and

Sherl L. Chapman Geologist

Prepared and Published by

Idaho Department of Reclamation

R. Keith Higginson

State Reclamation Engineer

JULY 1968

ACKNOWLEDGEMENTS

The Department of Reclamation and the authors wish to acknowledge the assistance of the Idaho Bureau of Mines and Geology in the preparation of this report. Sylvia Ross, Ground-Water Geologist for the Bureau, provided valuable field and interpretive assistance in the geological reconnaissance and water quality data compilation. The Bureau provided the chemical analysis and made available water level recorders and field equipment which helped to enlarge the scope of the investigation.

The loan of water level recorders by the Water Resources Division, U. S. Geological Survey is appreciated.

The cooperation of the many well drillers, tenants, and owners who supplied information and allowed access to wells is also gratefully acknowledged.

CONTENTS

ILLUSTRATIONS

TABLES

ABSTRACT

The Mountain Home Area consists of approximately 750 square miles of land in southwestern Idaho including the high relief Mt. Bennett Hills, the rolling upland plain known as the Mountain Home Plateau, and the Snake River Canyon. Ground water is used as the primary source of domestic and irrigation supplies over most of the area.

The geologic formations within the study area are divided into four general subdivisions: Idavada Silicic Volcanics, Idaho Group sediments and basalt, Snake River Group gravels and basalt, and unconsolidated younger sediments. The exposures of the Idavada Volcanics along the Mt. Bennett Hills are the primary source areas for recharge to the aquifers in the study area. Two of the formations of the Idaho Group, the Glenns Ferry and the Bruneau, are the main aquifer systems. The Glenns Ferry Formation, a thick intertongueing deposit of lake and stream sediments, is the primary aquifer in the eastern portion of the study area. The sediments and basalt of the Bruneau Formation are the primary aquifers in the western portion of the study area. The formations of the Snake River Group and the unconsolidated sediments are generally above the regional water table and are not important aquifers.

The ground-water potential in the Mountain Home area can be delineated on the basis of varying geologic and hydrologic conditions. The Bruneau Formation in the western portion of the study area yields large quantities of water to wells at pumping lifts of approximately 390 feet. The short record of water level fluctuations available does not indicate

a significant decline in the area as a result of the large scale irrigation development. The Bruneau Formation thins rapidly from west to east which coincides with a decrease in yields to wells in the same direction. The change from the Bruneau Formation in the west to the Glenns Ferry Formation in the east is also marked by a change in water quality from good or excellent to poor or unsuitable. The Glenns Ferry Formation in the eastern portion of the study area yields only small quantities of water to wells with discharges of 20 to 100 gpm common.

A perched ground-water system in and north of the city of Mountain Home supplies water for domestic and small irrigation wells. The ground water is derived primarily from the basalts and sediments of the Bruneau Formation.

Hot artesian flowing wells have been developed near the Mt. Bennett Hills east of Mountain Home. The hot water issues from a series of northwest trending faults along the mountain front. Decline in artesian pressure in this area is evident because of the present well development.

INTRODUCTION

Purpose

Development of the ground-water resource of the State of Idaho has accelerated in recent years to one of the highest rates in the nation. This growth has been accompanied by many problems including water level declines and interference between wells. The Idaho State Reclamation Engineer has the responsibility for administering both the surface-water and ground-water rights of the state to assure that the resource is utilized to its fullest, yet preserved for continual use in the future. He has assumed an active role in the investigation of areas in which the present rate of development of ground water might affect the future use of the resource and has also authorized investigations of other areas in which problems already exist. This report is the first resulting from such an investigation.

The purpose of this study is threefold:

1. To aid the State Reclamation Engineer in administering the water rights within the area,

2. To obtain a greater knowledge of the hydrology and geology of the area in order to assist land owners in developing the ground-water resource, and

3. To generally add to the knowledge of the water resource of the State of Idaho.

Objectives

The primary objectives of the project are to determine the effect of the recent ground-water development on the general hydrologic system and the future use of the ground-water resource. The more specific objectives are to: 1) study the general geology of the area with special emphasis on the geologic control of the occurrence of ground water, 2) determine the source of the hot artesian ground water and define its inter-relationship to the other ground water in the area, 3) determine the geologic and hydrologic characteristics of the aquifer system in the area, and 4) denote areas where special consideration is needed in administering the use of the ground-water resource.

Location and Extent

The Mountain Home area includes approximately 750 square miles located entirely in Elmore County (fig. 1). It is bounded on the south by the Snake River, on the north by the Mt. Bennett Hills, on the east by King Hill Creek, and on the west by Canyon Creek.

The field work, conducted during the period of July through September 1967, included examining geologic formations and collecting well logs and other well data. Five water level recorders were operated during the study with one mass measurement of water levels conducted during September 1967. Ground-water samples from 26 locations in the study area were collected and chemically analyzed.

Previous Investigations

The ground-water hydrology of the Mountain Home area has not been investigated in any previous study. Malde, Powers, and Marshall conducted reconnaissance mapping of the geology of the western Snake River Plain. The resulting report (Malde and Powers 1962) and map (Malde, et al 1963) were used as the basis for the geologic investigation during this study. A small portion of the study of the Mountain Home project (Nace, West and Mower 1957) was useful in the present study. Data were also obtained from Dion and Griffiths (1967)

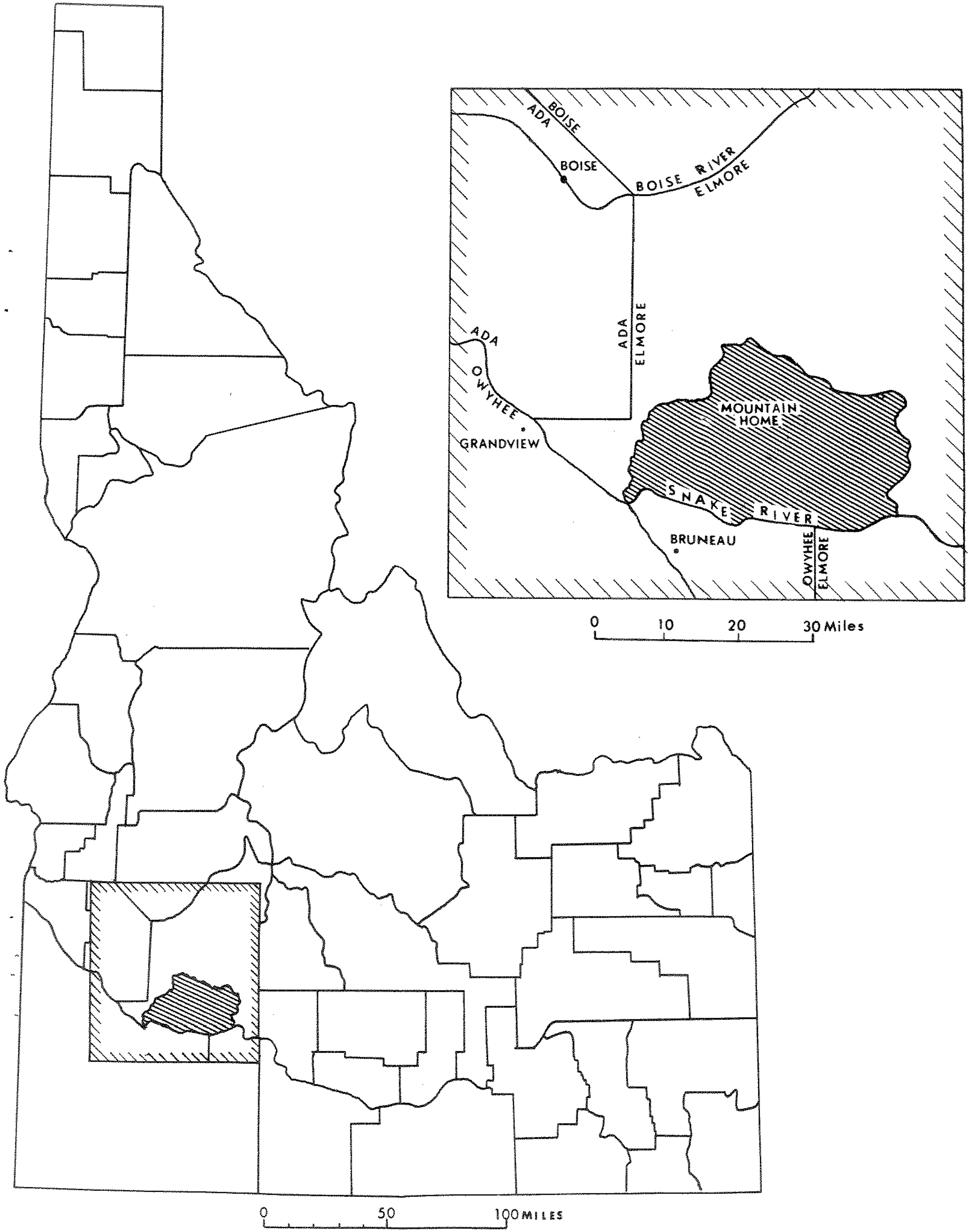


Figure 1.--Index map showing the area covered by this report.

as a result of field work conducted in setting up the southwestern Idaho observation well network.

Well Numbering System

The well numbering system used in this study is the same as that used by the U. S. Geological Survey in Idaho. This system indicates the locations of wells within the official rectangular subdivisions of the public lands, with reference to the Boise Base Line and Meridian. The first two segments of a number designate the township and range. The third segment gives the section number, followed by two letters and a numeral, which indicate the quarter section, the forty acre tract, and the serial number of the well within the tract. Quarter sections are lettered a, b, c, and d in counterclockwise order, from the northeast quarter of each section (fig. 2). Within the quarter sections, forty acre tracts are lettered in the same manner. Well 4S - 5E 10 aa1 is in the NE$\frac{1}{4}$NE$\frac{1}{4}$ of sec. 10, T. 4S., R. 5 E., and is the first well designated in that tract.

Geographic Setting

The Mountain Home area is comprised of three definite geographic features: Mt. Bennett Hills, Mountain Home Plateau, and Snake River Canyon. The Mt. Bennett Hills are a high relief mountainous region along the northern boundary of the study area. The hills average 6000 feet in elevation (mean sea level datum) with a maximum of 7465 feet at Mt. Bennett. The Mountain Home Plateau is a rolling upland plain, much of which is mantled by wind blown sediments. The plateau slopes from a maximum elevation of about 4000 feet near the Mt. Bennett Hills to an elevation of 3000 feet near the Snake River. Several cinder cones and shield volcanos rise above the

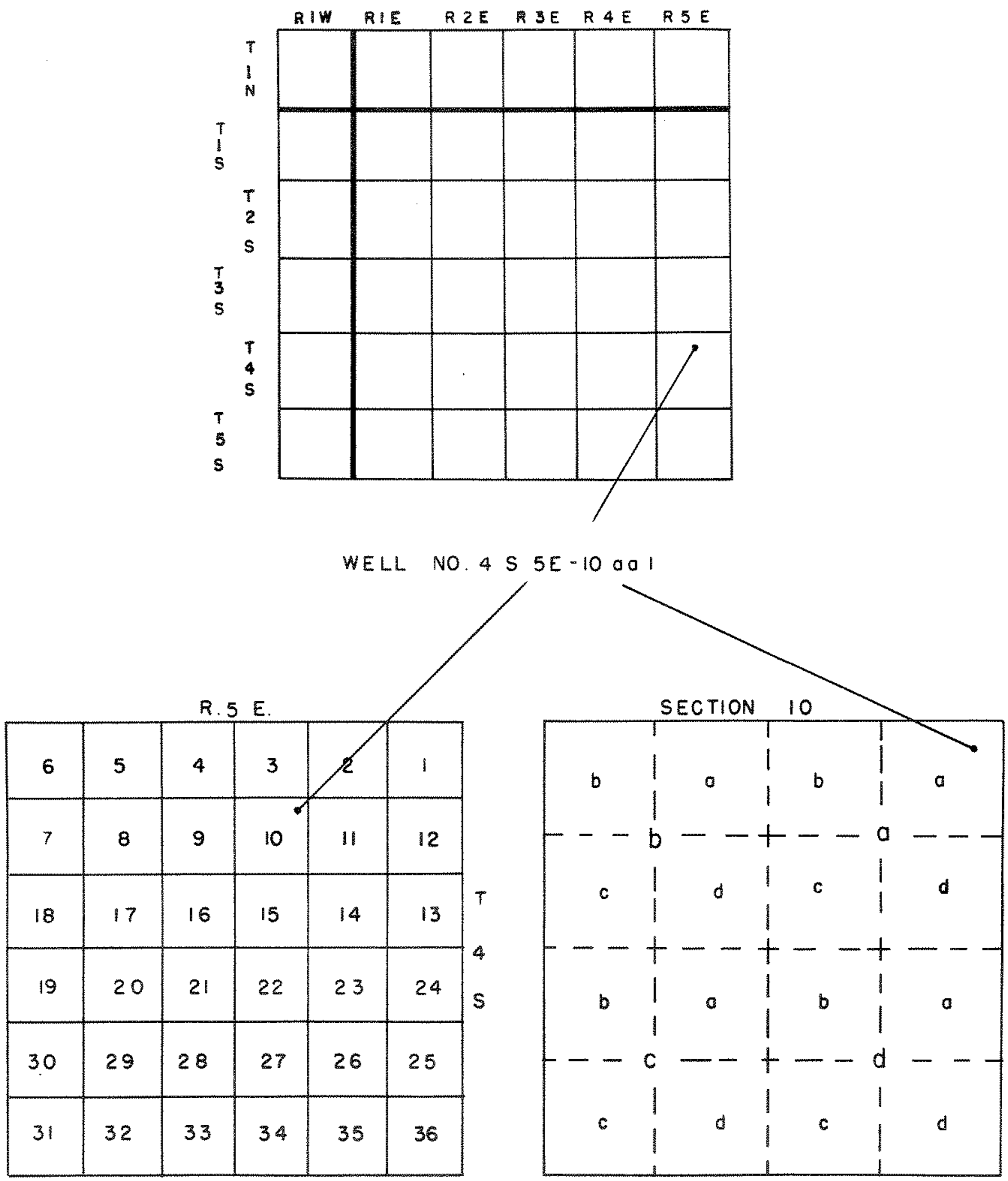


Figure 2.--Well numbering system

surface of the plain near Mountain Home. The Snake River, along the southern boundary of the area, flows in a canyon from 300 to 500 feet below the surface of the plain and forms the third geographic feature.

Many of the streams in the area are ephemeral. Canyon, Rattlesnake, and Little Canyon Creeks, tributaries of the Snake River, are controlled by storage in the upper reaches. Bennett and Cold Springs Creeks flow uncontrolled into the river. The area contains many draws, gulches, and small creeks of minor importance, all of which flow to the Snake River.

The climate of the area is semi-arid with hot summers and cool to cold winters. The mean monthly precipitation and temperature for the five U. S. Weather Bureau stations nearest the area are shown in Table 1. The average annual temperature of the area is estimated to be 50° F with the average annual precipitation estimated as 8.9 inches.

Sage brush is the predominant native vegetation with areas of rabbit brush, greasewood, and cheat grass. Willows and alders are present in the stream valleys at higher elevations in the Mt. Bennett Hills with occasional groves of pine and fir.

All of the crops in the area depend on irrigation. Surface water is used near Mountain Home, along the Snake River from Glenns Ferry to Hammett, and at isolated areas near the Mt. Bennett Hills. Irrigation water is pumped from the Snake River for a large development east of Highway 51. The remainder of the area depends on ground water. Mountain Home, Hammett, and Glenns Ferry are the only settlements in the area with the exception of the resident personnel at the Mountain Home Air Force Base.

TABLE 1
AVERAGE MONTHLY PRECIPITATION AND TEMPERATURE
AT STATIONS NEAR THE MOUNTAIN HOME AREA

	Mountain Home		Glenns Ferry		Hill City		Anderson Dam		Grandview*
Elevation	3180 feet		2570 feet		5000 feet		3882 feet		2600 feet
Yrs. of Record	1906-65		1905-65		1915-65		1942-52		1909-65
Month	Precip. (in.)	Temp. (°F)	Precip. (in.)	Temp. (°F)	Precip. (in.)	Temp. (°F)	Precip. (in.)	Temp. (°F)	Precip. (in.)
January	1.04	28.3	1.25	30.0	2.32	15.3	2.31	22.7	0.71
February	0.87	33.2	0.94	35.0	1.94	19.5	3.18	28.7	0.58
March	1.10	40.4	1.02	43.0	1.41	26.8	1.95	35.5	0.91
April	0.84	49.6	0.75	52.9	1.01	40.5	1.02	47.9	0.70
May	1.02	57.4	0.90	60.9	1.26	50.0	1.29	55.6	1.09
June	0.73	64.4	0.59	66.9	0.85	57.3	1.11	61.3	0.83
July	0.24	73.7	0.25	75.6	0.27	65.8	0.16	73.1	0.16
August	0.15	71.1	0.14	72.4	0.33	63.7	0.10	71.5	0.11
September	0.30	62.2	0.25	63.2	0.41	54.7	0.51	62.9	0.33
October	0.65	51.9	0.55	53.3	1.00	44.3	1.36	52.1	0.47
November	0.93	38.7	1.05	40.2	1.71	30.6	2.36	37.6	0.68
December	0.91	31.9	0.99	33.4	2.18	21.8	3.55	29.0	0.69
Total	8.78		8.68		14.69		19.17		7.26
Average		50.2		52.3		40.8		48.2	

* Temperature records are not obtained at this station

GEOLOGY

Geologic Formations

The geologic formations within the study area consist of volcanic and clastic rocks of Pliocene to Recent age. They may be divided into four general subdivisions according to mode of deposition and lithology. The subdivisions are as follows: 1) Idavada silicic volcanic rocks, 2) Idaho Group sediments and basalt, 3) terrace gravels and basalts of the Snake River Group, and 4) unconsolidated sediments. These subdivisions are separated by major unconformities with smaller units separated by uncomformities of a lesser magnitude. The composite thickness of the rock units is approximately 6200 feet. The stratigraphic sequence of the formations is shown in Figure 3.

Idavada Volcanics

The exposures of the Idavada Volcanics along the northern edge of the study area are the primary source areas for recharge to the aquifers in the Mountain Home area. The jointing and fracturing of the rocks allow a high vertical permeability, and faulting provides avenues for circulation and heating of ground water at depth.

The Idavada Volcanics are primarily composed of welded ash flows, chemically defined as silicic latite (Malde & Powers 1962, p. 1201). The rocks, although gray when fresh, are generally deeply weathered to a reddish brown color. Abundant light gray plagioclase phenocrysts averaging 3 to 7 mm (millimeters) in length are present in fresh specimens. Black perlitic vitrophyre beds up to 5 feet in thickness are present at the base of some of the flows. Well developed columnar jointing is characteristic

SERIES			GROUPS AND FORMATIONS	
QUATERNARY	RECENT		SNAKE RIVER GROUP	Recent lava flows
QUATERNARY	PLEISTOCENE	UPPER	SNAKE RIVER GROUP	Melon Gravel*
				Bancroft Springs Basalt
				Sand Springs Basalt
				Crowsnest Gravel*
				Thousand Springs Basalt
				Sugar Bowl Gravel*
				Madson Basalt
		MIDDLE	IDAHO GROUP	Black Mesa Gravel
				Bruneau Formation*
		LOWER		Tauna Gravel
				Glenns Ferry Formation*
TERTIARY	PLIOCENE	UPPER		
		MIDDLE		Chalk Hills Formation
				Banbury Basalt*
		LOWER		Poison Creek Formation
			Idavada Volcanics*	

*Formations present in Mountain Home study area

Figure 3.--Sequence of Cenezoic rocks in the western Snake River Plain

of the Idavada Volcanics. Platy horizontal jointing, probably due to release pressures, has developed to a lesser degree. The vitrophyre beds lack the well developed jointing present in the rest of the unit and probably act as aquicludes, causing horizontal ground-water flow. The maximum thickness of the formation is unknown.

The Idavada Volcanics had undergone considerable erosion and deformation prior to deposition of the overlying Banbury Basalt. This disconformity is best exposed near the headwaters of Bennett Creek in the Mt. Bennett Hills. Stratigraphic relationships and fossils (Malde & Powers 1962, p. 1201) indicate a Lower Pliocene age for the Idavada Volcanics.

Idaho Group

The Idaho Group was redefined by Malde and Powers (1962, p. 1201-02) to include the clastic and volcanic rocks previously named the Idaho Formation. These Lower Pliocene to Middle Pleistocene rocks consist of consolidated but nonindurated clastic beds with interbedded basalts. These rocks have been divided into seven formations: 1) Poison Creek Formation, 2) Banbury Basalt, 3) Chalk Hills Formation, 4) Glenns Ferry Formation, 5) Tuana Gravel, 6) Bruneau Formation, and 7) Black Mesa Gravel. Only the Banbury Basalt, Glenns Ferry Formation and Bruneau Formation are present in the study area. Although these three formations are not exposed as a continuous sequence in the study area, their composite thickness is estimated as 4,000 feet.

Banbury Basalt - The Banbury Basalt is not an important aquifer in the Mountain Home study area. The exposures of the basalt may serve as minor source areas for recharge to the aquifers in the Mountain Home area. The permeability of the basalt is believed to be high because of the vesicular nature of the rock and its well developed jointing.

The only major outcrops of the Banbury Basalt exposed in the study area are near the headwaters of Bennett Creek and on Teapot Dome, 9 miles northeast of Mountain Home (plate 1). The formation consists of gray to gray black, brown-weathering vesicular basalt with phenocrysts of light gray plagioclase up to 10 mm in diameter. Olivine is present as small, olive-green, anhedral crystals in fresh samples but has been highly altered in weathered specimens. Vertical columnar jointing is well developed in most of the outcrops. Platy horizontal joints have developed in the more weathered outcrops. Two phases of weathering may be seen in the Banbury Basalt. A weathering rind approximately 10 mm in thickness is present on most of the flows exhibiting columnar jointing. This rind is yellow to yellowish-brown and is quite soft. In other areas the basalt has weathered to a brown rubble or basaltic saprolite. This highly altered phase of the Banbury Basalt was encountered at a depth of 2100 feet in well 30 bb1, T. 4 S., R. 10 E. The exposed thickness of the formation ranges from approximately 100 feet upon Teapot Dome to approximately 500 feet at High Spring on Bennett Creek. The Banbury Basalt had undergone considerable erosion prior to Upper Pliocene deposition. Shallow canyons and gullies were present during encroachment of ancient Lake Idaho. The contact marks the end of Tertiary vulcanism and the beginning of Plio-Pleistocene sedimentation. The fossils from the formation, identified as Middle to Late Pliocene (Malde & Powers 1962, p. 1199), and the stratigraphic position leave little doubt that the Banbury Basalt is of Middle Pliocene age.

<u>Glenns Ferry Formation</u> - The Glenns Ferry Formation contains a large volume of ground water. However, because of the fine grained nature of the sediments, the permeability and yield to wells is generally low. Sand lenses within the formation have higher permeability but are generally too discontinuous to be important sources of ground water. Most of the ground water pumped from the formation has a high dissolved solids content and is poor to unsuitable for irrigation.

The Glenns Ferry Formation is a thick intertongueing deposit of lake and stream sediments. The formation can be separated into three facies: lacustrine, fluviatile, and flood plain. The lacustrine facies consists of tan to white clay, silt and very fine sand, generally massive to thickly bedded. Diffuse light gray bands traverse many of the exposures. These deposits constitute the greatest volume of the Glenns Ferry Formation exposed in the study area. The fluviatile facies consists of light gray to white, silty, fine to medium sand. These sediments, which range from thin to thickly bedded, are partially cemented by silica. Many of the beds have been reworked and are complexly cross bedded. The flood plain facies, present at only one location in the study area, consist of thinly bedded, gray to olive silt and clay. Plant remains, present along many of the bedding planes, are generally altered to fragile carbonaceous fragments. The formation has been noted as being 2000 feet thick near Glenns Ferry (Malde & Powers 1962, p. 1206). Approximately 1100 feet of the formation has been encountered in well 13 aa1,

T. 4 S., R. 7 E., with drilling in the formation to be continued. The members of the formation are extremely discontinuous because of the mode of deposition. Lateral and vertical variation of grain size and thickness of beds cause difficulty in tracing individual units from one location to another. The lake beds of the formation erode to chalk-white knobs and bluffs often greater than 100 feet in height. The fluviatile facies is more resistant, but more thinly bedded and forms low standing gray white ledges. Deposition ceased during the Early Pleistocene and the soft sediments of the Glenns Ferry Formation were eroded into deep canyons and gullies. Before the sediments were eroded to base level however, a new period of vulcanism and sedimentation began. The discomformity is well exposed at several locations in the study area.

The Glenns Ferry Formation contains a large and varied fossil assemblage. Vertebrate, invertebrate, and floral fossils have been identified by various collectors (Malde & Powers 1962, p. 1208-09). It is on this basis that the formation has been assigned to the Late Pliocene or Early Pleistocene.

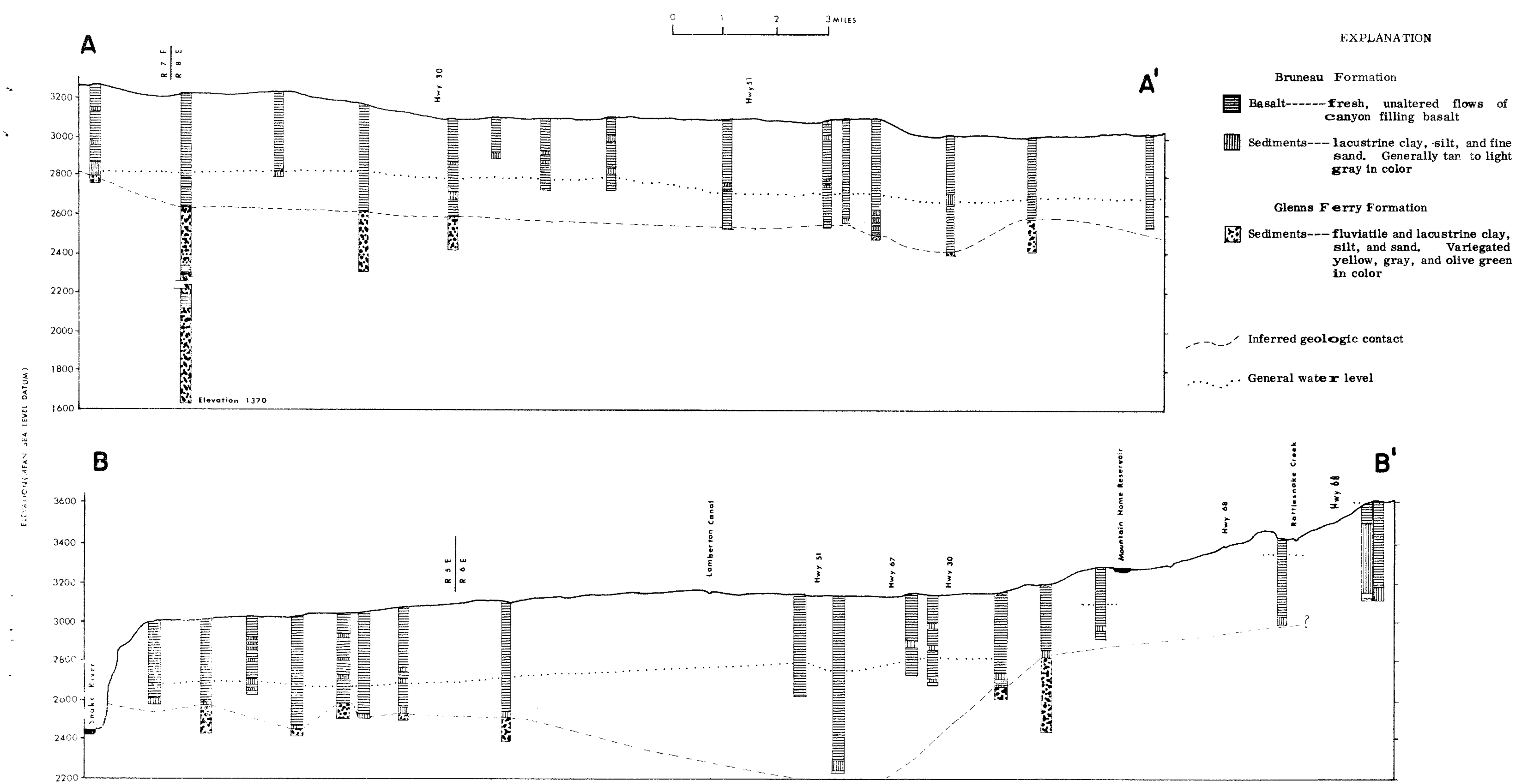
Bruneau Formation - The Bruneau Formation is a principal aquifer in the Mountain Home area. The jointing, fracturing, and vesicular character of the basalts cause them to be very permeable. The majority of ground-water withdrawal from the formation is from the deeper interflow zones and a thin but extensive series of arkosic sand beds just below the lowest basalt unit.

The Bruneau Formation, at the type locality, consists of approximately

1500 feet of lake and stream sediments with numerous basalt interbeds. However, the formation is best represented in the study area by 500 to 600 feet of canyon filling basalt flows (fig. 4), overlain by about 300 feet of sediments and fan gravels at higher elevations near the Mt. Bennett Hills. The volcanic rocks of the Bruneau Formation were extruded from an extensive chain of volcanos, most of which were located between the Snake River and the Mt. Bennett Hills (see plate 1). The lava was deposited on the highly eroded Glenns Ferry topography filling canyons and gullies. These plagioclase-olivine basalts are dark gray to black when fresh but weather to a reddish gray-brown color. Elongate vesicules are common throughout the rock and grade into scoracious interflow zones. Most of the interflow zones contain large quantities of glassy cinders and some ash. Pillow basalts with vesicular cores, black glassy rinds and radial jointing patterns are exposed at several locations in the Snake River canyon. Many of the pillows are enclosed in a mass of yellow, waxy appearing palagonite. Well developed columnar jointing is present throughout the basalt. Most jointing is vertical, but radial sets have developed in pressure ridges and are exposed at many locations along the north canyon wall. Well drillers' reports indicate this jointing extends throughout the formation. The Bruneau Formation thins rapidly from west to east on the north side of the Snake River. Wells in T. 4 S., R. 5 E. encountered 500 to 560 feet of the formation while only 78 feet was present in well 36 cc1, T. 4 S., R. 8 E. This eastward thinning coincides with a rapid decrease in well yield.

Bruneau age sediments in the area consist of approximately 200 feet

Figure 4.-- Generalized Geologic Cross Sections



of light gray and tan sand, silt, and clay, and 100 feet of fan gravel. The silt and clay are rarely bedded and often exhibit "popcorn" weathering, a feature attributed to a high bentonite content. The sand, usually fine to very fine, is generally present at the base of the lowest basalt flows and as thin interbeds between flows. These deposits are probably the result of streams carrying granitic detritus material from high in the mountains to the north. The fan gravel consists of angular basalt pebbles and welded tuff fragments in a matrix of brown devitrified volcanic glass shards. The deposit generally weathers to a soft brown mass resembling a mudflow. Two beds of discontinuous beach gravels were encountered near Loveridge Bridge on the Snake River. The lower bed outcrops at elevation 2680 feet and is composed predominantly of pebble to cobble size quartzite and porphry. The higher gravel, exposed at elevation 2710 feet, is composed almost entirely of basalt pebbles. Both gravel beds are imbricated and the higher is heavily stained with reddish-brown iron oxide. These gravel units are permeable but too discontinuous to be considered as important aquifers. The basalt of the Bruneau Formation forms prominant cliffs along both sides of the Snake River. The sediments erode to monotonous gray and tan badlands with conspicuous terraces formed where the resistant beach gravels are exposed.

Fossils collected in the Bruneau Formation are both vertebrate and invertebrate. Most collectors agree that the age of these fossils date from Middle to Late Pleistocene (Malde & Powers, p. 1211-1212). Because of this and the relationship of the formation to other units in the

Idaho Group, the Bruneau Formation has been assigned a Middle Pleistocene age. The contact between it and the overlying Snake River group marks a major unconformity in the stratigraphic sequence.

Snake River Group

The formations of the Snake River Group are generally above the regional water table in the area and are not important aquifers. The Snake River Group is composed of seven Upper Pleistocene Formations: (1) Madson Basalt, (2) Thousand Springs Basalt, (3) Sand Springs Basalt, (4) Bancroft Springs Basalt, (5) Sugar Bowl Gravel, (6) Crowsnest Gravel, and (7) the Melon Gravel. The basalt units of the group are collectively termed the Snake River Basalt. The Snake River Basalt and all of the gravel formations are exposed within the study area although not at any single locality. The formations range from 20 feet to 500 feet in thickness and have a maximum composite thickness of approximately 850 feet.

Sugar Bowl Gravel - The Sugar Bowl Gravel is best exposed as a resistant cap on the Sugar Bowl, a hill 4 miles northeast of Glenns Ferry. The unit is composed almost entirely of pebble to cobble size granite, porphry, and quartzite. The gravel outcrops are remnants of a river terrace 400 feet above the present channel of the Snake River. The terrace was formed during a period of augmented runoff probably a result of the melting of alpine glaciers to the north. The freshness of the gravel and its stratigraphic position indicate deposition during a Late Pleistocene glacial period.

Crowsnest Gravel - The Crowsnest Gravel is exposed in the study area at five localities: 3 miles west of King Hill, 3 miles northwest of Glenns

Ferry, one mile north of the Snake River near Highway 51, 1.5 miles east of Hammett and along Bennett Creek near U. S. Highway 30. The gravel consists primarily of imbricated, pebble to cobble size quartzite, porphry, and granite with minor amounts of basalt, and is approximately 25 feet in thickness. Lenticular beds of gray basaltic sand and gravel are present in the outcrop near Loveridge Bridge. The Crowsnest Gravel was derived from north of the Mt. Bennett Hills and carried to the area by a tributary stream of the Snake River. These gravels were deposited on terraces during an interval of augmented runoff, probably coincident with glacial melting. The suggested mode of deposition and lithology indicate the Crowsnest Gravels are of Late Pleistocene age.

Snake River Basalt - The Snake River Basalt includes the volcanic rocks of Late Pleistocene age present in the study area. These basalts were extruded from a series of vents west and north of Mountain Home, (plate 1) and flowed southward toward the Snake River. The rocks consist of vesicular, plagioclase-olivine basalt. When fresh, the basalt is dark gray to black and weathers to a dark reddish-brown. The individual flows range from 5 to 20 feet in thickness, with a composite thickness of approximately 500 feet. The majority of the flows have well developed vertical columnar jointing and a typical ropy or pahoehoe surface. The basalt is scoraceous in the interflow zones and baking has occurred at many contacts. Northwest of Mountain Home, the flows form low benches gaining in elevation northward toward the eruptive centers. The lava is generally covered by alluvium and wind blown silt but is exposed at flow edges and along the Snake River canyon. The Snake River Basalt is the youngest consolidated unit in the area.

Melon Gravel - The Melon Gravel was deposited during a Late Pleistocene catastrophic flood, which originated from ancient Lake Bonneville in northern Utah. The lake overflowed and discharged through Red Rock Pass near the Idaho-Utah border, and entered the Snake River Canyon via Marsh Creek and the Portneuf River. The flood had a peak discharge of approximately 15 million cfs (cubic feet per second), and a possible continuous discharge for almost one year (H. E. Malde, oral comm. Aug. 26, 1967). Discontinuous outcrops of gravel deposited by the flood exist as far down the Snake River as Homedale and are derived almost entirely from local basalts. The three major physiographic features of the gravel are eddy bars, backwater deposits, and boulder terraces. The boulder terraces and eddy bars are commonly found just downstream of canyon constrictions and abrupt changes in the river course. Boulders in these terraces generally have more angular side facing in the same direction indicating water flow orientation. The backwater and eddy bar deposits are predominantly fine to coarse sand and comprise the bulk of the sediments.

Unconsolidated Sediments

Unconsolidated deposits of Recent age mantle a large part of the Mountain Home plateau. Alluvial fans along the mountain front are composed primarily of latite and basalt debris. The fans attain a maximum thickness of about 50 feet near the apex and thin to a feather edge. Sand and gravel, deposited as stream alluvium, are present in the lower reaches of the ephemeral streams in the area. These sediments are generally well sorted and consist primarily of latite and basalt detritus. Extensive talus slopes of angular basalt boulders are present in the Snake River canyon. These slopes are dark brown in color and many extend to river level. Landslides are present in many of the alcoves and tributary canyons of the Snake River. Loess is exposed at scattered locations throughout the area. The sediment supports only sparse vegetation and outcrops are usually thin.

Geologic Structure

The Snake River plain is a broad downwarped structural basin bounded by low mountain ranges and complex fault systems. The study area is located near the center of the western part of this plain. Faults and dikes are the predominant structural features in the area. The extensive series of normal faults exposed in the Idavada Volcanics (plate 1) along the Mt. Bennett Hills front are the most conspicuous structural features within the area. These faults have an average trend of N. 40° W., dip 70°-80° S.W. and have the downthrown block to the south. Drag folds and narrow shattered zones are common adjacent to the faults. Related faults with similar attitudes are probably buried beneath the younger rocks exposed within the structural basin. The fracturing of the rocks in the fault zone are believed to form highly permeable avenues for circulation of ground water. Some of the ground water in these zones is probably channeled to the general aquifer system while much of it is circulated and heated at depth.

Basalt dikes are exposed in the canyon of the Snake River downstream from Hammett. These dikes intruded into the sediments of the Glenns Ferry Formation, drag folding and baking them at some locations. The dikes trend N. 97° E. to N. 65° E., dip from 68-89° N.W. and are believed to be feeders for Pleistocene vents in the area. Similar dikes are believed to be present beneath the shield volcanos north of Mountain Home. These dikes do not appear to be extensive enough to have a significant effect on the movement of ground water.

Cenezoic Geologic History

Tertiary Period

Basaltic, rhyolitic, and clastic rocks were deposited throughout southwestern Idaho from Eocene to Late Miocene time. These rocks, deposited nonconformably upon Cretaceous granitic rocks, now form most of the marginal highlands surrounding the Snake River plain. Erosion during the Late Miocene and Early Pliocene created an uneven topographic surface upon which silicic volcanic rocks were deposited during the Early Pliocene. A slow downwarping of the Snake River Plain began at the close of this volcanic episode, resulting in large scale block faulting. Basic lavas flowed from vents north of the Snake River during the late stages of faulting. These basalts are not as widespread as the silicic volcanic rocks and exhibit a lesser degree of faulting. The subsidence of the plain created an extensive structural basin in which large volumes of lacustrine sediments were deposited during the Late Pliocene. These sands, silts, and clays have an estimated thickness of more than 3000 feet and extend to below sea level.

Quaternary Period

Subsidence of the Snake River plain decreased in magnitude during the Early Pleistocene, allowing fluviatile and flood plain environments to become established. Deep canyons and gullies were eroded into the soft sediments as drainage systems developed. Gravel from plutonic source areas to the north was deposited adjacent to the Snake River and preserved as resistant caps on terrace remnants. Subsidence of the Snake River plain continued into the Middle Pleistocene. Basic lavas flowed from vents primarily north of the Snake River at this time. These basalts intermittently dammed the Snake River forming large impoundments where silt and clay were deposited in massive layers. Minor unconformities, present in the sediments, indicate breaching of the lava dams and subsequent erosion. Entrenchment of the Snake River accelerated as vulcanism ended with the various stages indicated by terrace remnants at several elevations. A catastrophic flood passed through the Snake River canyon during Late Pleistocene time. This flood, known as the Bonneville flood, filled the Snake River canyon cutting marginal channels and depositing great amounts of locally derived basaltic debris. During recent time, erosion of the older rocks and deposition of alluvium have been the principal geologic processes.

HYDROLOGY

Hydrologic Subareas

The study area was divided into five subareas for the hydrologic portion of the investigation. The delineation of these subareas was based upon variations in the following hydrologic or geologic conditions: water level elevation, well yield, water temperature, water quality, and geologic character of the aquifer material. The subdivisions of the study area were named as follows:

1. Mt. Bennett Hills Subarea
2. Hot Springs Subarea

3. Mountain Home Subarea

4. Air Base Subarea

5. Glenns Ferry Subarea

The boundaries of the subareas are shown in Figure 5.

Mt. Bennett Hills Subarea

The Mt. Bennett Hills subarea includes the south slope of the Mt. Bennett Hills. The east and west boundaries are King Hill and Canyon Creeks, with the south boundary the topographic edge or front of the Mt. Bennett Hills (fig. 5). This subarea is important as the primary area for recharge to the aquifers of the Mountain Home plateau.

The yearly rate of precipitation varies greatly over the subarea. Data from the three nearest weather bureau stations indicate yearly precipitation rates of 8.78 inches (Mountain Home), 14.69 inches (Hill City), and 19.17 inches (Anderson Dam). Four snow survey courses in the Mt. Bennett Hills indicate a maximum water content in the snow pack of 20.3 inches (Bennett Mountain), 8.2 inches (Dixie Hill), 10.6 inches (Little Camas Flat), and 7.8 inches (Long Tom) (Nelson and Wilson, 1964). These data indicate an average precipitation rate of approximately 20 inches per year.

Surface runoff from the Mt. Bennett Hills subarea is divided into six streams, all of which flow into the summer months. The discharge in Canyon Creek is regulated by Long Tom Reservoir on Long Tom Creek and by an intermountain diversion from Little Camas Reservoir, with the majority of the flow diverted into the Mountain Home Feeder Canal. Flow in excess of irrigation needs is routed to the Mountain

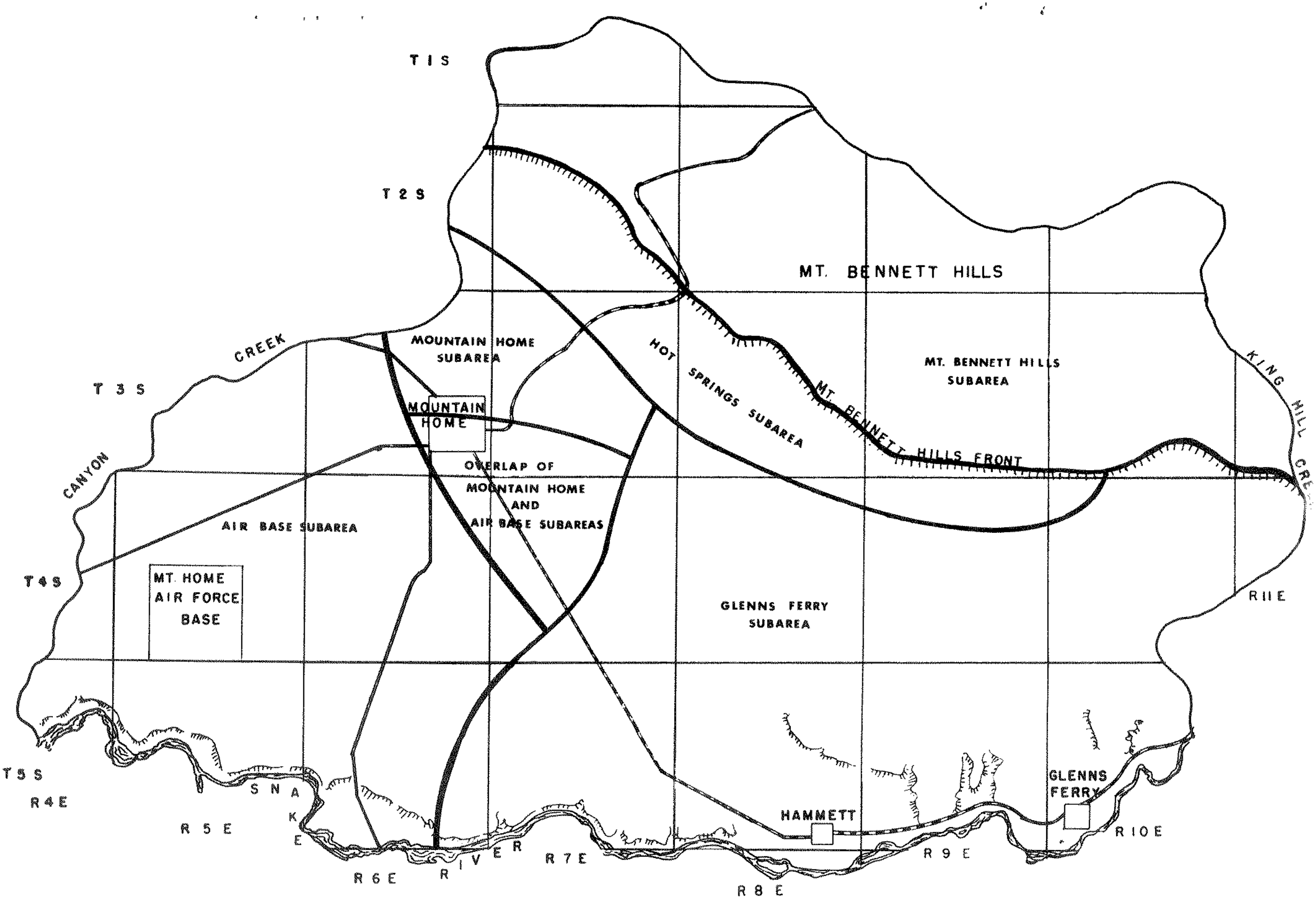


Figure 5.--Delineation of hydrologic subareas

Home Reservoir. The average daily diversion is 28 cfs (U.S.G.S., 1966, p. 176). The only other stream that is gaged, Little Canyon Creek, has an average daily discharge of 4 cfs at a point 13 miles north of Glenns Ferry (U.S.G.S., 1966, p. 175). This creek is partially diverted into the Blair and Trail Reservoir and is used for irrigation. The flow of Rattlesnake Creek is partially diverted for irrigation with remainder of the flow routed into Mountain Home Reservoir. The other streams, Bennett Creek, Cold Springs Creek, and King Hill Creek, are partially or wholly used for irrigation. Many small channels in the area carry flood discharge after periods of precipitation.

A number of small springs are located in the Mt. Bennett Hills subarea. Many of these discharge at approximately elevation 4200 feet indicating possible structural control. Residents of the area report that many of the springs are merely seeps which dry up in the summer months. Most of the springs are cold, ranging in temperature from 50 to 70° F. High Spring, in sec. 13, T. 3S., R. 8E., has a measured water temperature of 67° F. Warm to hot springs are reported to issue along Cold Springs Creek.

Ground-water recharge in the Mt. Bennett Hills subarea can be divided into two major portions: areal recharge, and recharge in the fault systems. The Mt. Bennett Hills are predominantly composed of silicic latite of the Idavada Volcanics (Malde & Powers, 1962). The areal recharge in the Mt. Bennett Hills is considered to be high because the columnar jointing of the formation allows a high infiltration rate. A number of subparallel northwest-trending faults border the southern edge of the subarea. These fault zones, examined near Bennett and Cold Springs Creeks, are highly fractured and jointed. The zones appear to be highly pervious and could act as efficient recharge conduits. Although quantitative assessments were not made on the total loss in streamflow across the fault systems, the effective recharge is believed to be high.

Ground-water development is limited in the Mt. Bennett Hills subarea. A few of the springs have been cleaned and fenced for stock use by local residents. The only well in operation in the subarea, located in sec. 14, T. 2 S., R. 7 E., is 490 feet deep, and has a reported depth-to-water of 205 feet and a yield of 7 gpm (gallons per minute). The well drillers report indicates the primary rock encountered as latite, identified as the Idavada Volcanics. The subarea is generally not an important source of ground water.

Hot Springs subarea

The Hot Springs subarea includes the occurrence of hot artesian water along the front of the Mt. Bennett Hills from the west boundary of the study area to approximately R. 10 E. The southern boundary of the subarea is an arbitrary line denoting the southern-most development of the hot water under high artesian pressure (fig. 5).

A yearly rate of precipitation over the subarea of 10 inches per year was estimated from data available for the Mountain Home Weather Bureau station. This rate is greater than that at Mountain Home because of the higher elevation of the subarea. The runoff from this subarea is estimated to be small. The streams emitting from the Mt. Bennett Hills are depleted as they flow through the area, indicating some recharge to the ground-water system.

Several large hot springs and many small cold springs are located in the Hot Springs subarea. Hot Springs, in sec. 16, T. 3 S., R. 8 E., have an estimated natural discharge rate of 560 gpm (Anderson, 1966, p. 4), and an average water temperature of 150° F. The flow of the springs is diverted to the Hot Springs Reservoir and used for irrigation. Latty Hot Springs, in sec. 32, T. 3 S., R. 10 E., have a smaller discharge and a water temperature of 143° F. This flow is used for both domestic and irrigation supplies. The largest of the many cold water springs is an unnamed spring located in sec. 3, T. 3 S., R. 7 E., which has a perennial flow and is used for irrigation.

The ground-water recharge originating in the Hot Springs subarea is derived from three major sources: precipitation, irrigation seepage, and streamflow. The recharge becomes part of a series of discontinuous cold water aquifer systems, as very little recharge originating within the subarea is believed to reach the hot water system. Quantitative data are not available on the total recharge within the subarea.

Twenty-two wells have been reported drilled in the subarea for both domestic and irrigation purposes. The locations of the wells and two major springs in the area are shown in Figure 6, with the following data presented: depth of well, depth to water, and water temperature. The wells and springs can be divided into two groups on the basis of water temperature. Hot (100-160° F) water is present at three locations in the subarea at three water level elevations. The flow at Latty Hot Springs is the highest occurrence of hot water in the subarea. This spring issues at an elevation of

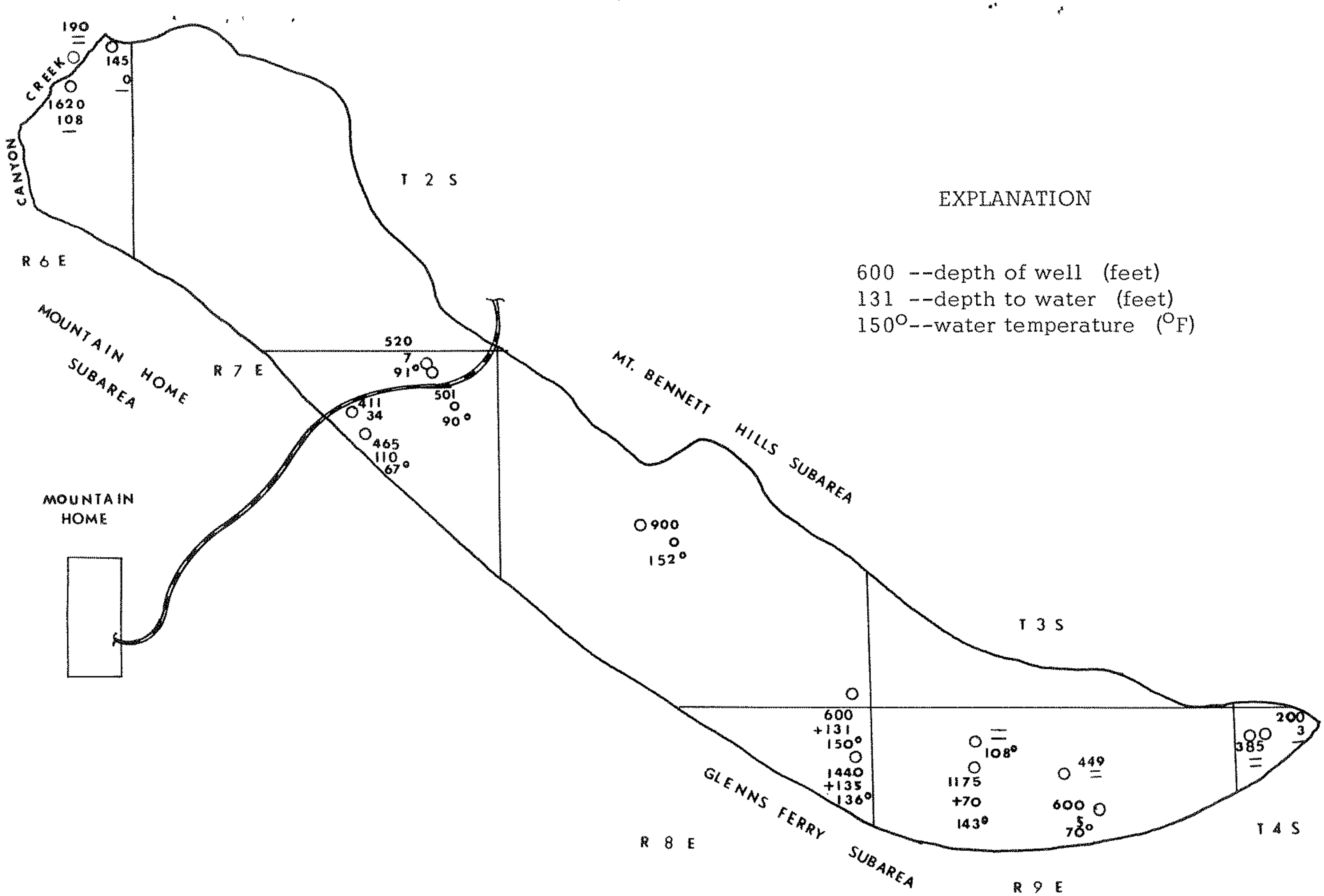


Figure 6.--Location, depth, depth to water, and water temperature of most of the wells in the Hot Springs subarea

4,000 feet from a fault line in the Idavada Volcanics. The second occurrence of hot water includes the Hot Springs and the wells located in sec. 10 (Lee) and 36 (Ross) T. 3 S., R. 8 E., sec. 1, T. 4 S., R. 5 E. (Lee), and two wells in sec. 5, T. 5 S., R. 8 E., (Walker and Blackwell). The elevation of the piezometric or pressure surface ranges from 3,500 to 3,555 feet. The hot artesian water is derived from sand and basalt which is overlain by a thick lens of clay and silt. The area of recharge for this zone is the Mt. Bennett Hills. The third occurrence of hot water is a well in sec. 11, T. 2 S., R. 6 E. (Mountain Home Irrigation District). The warm to hot water has a piezometric surface elevation of 3,300 feet. The well has a low yield and is presently not in use.

The existence of hot artesian water along the southern edge of the Mt. Bennett Hills is controlled by a series of subparallel northwest-trending faults. These faults are believed to allow both the downward flow of cold recharge water to the source of heat, and the upward flow of hot water and steam. Most of the heating is believed to be accomplished by the deep circulation of ground water, with possibly some residual heat supplied from the Late Pleistocene and Recent volcanics. The three occurrences of hot water is the subarea at different elevations are believed to be the result of flow along three separate fault zones. The extent of hydraulic interconnection of the occurrences is not known.

The cold ground-water system has been developed at four different locations in the Hot Springs subarea. The wells in sec. 6, T. 4 S., R. 10 E. (Steen), intercept the sands, clays, and basalts of the Glenns Ferry and Bruneau Formations. Three of the five wells drilled in the area are dry holes; the two producing wells have low yields. The wells in secs. 3, 8, and 10, T. 4 S., R. 9 E. (Walker), also intercept the Glenns Ferry and Bruneau Formations. Cold artesian water is derived from a sand and gravel strata. The wells in secs. 2, 3, and 10, T. 3 S., R. 7 E. (Ford and Duffy), intercept the sediments and basalts of the Bruneau Formation. The wells in sec. 2 are 500 feet deep and have a piezometric surface elevation of 3,426 feet and a water temperature of 90° F. These wells might represent a composite of the hot and cold water systems. The wells in secs. 3 and 10 yield cold water (66° F), at a lower elevation. The wells near Canyon Creek in secs. 1 and 11, T. 2 S., R. 6 E., also intercept the clay, sand, and basalt of the Bruneau Formation. The water is derived primarily from fractures and jointing in the basalts. The yield of these wells in unknown.

The cold ground water in the Hot Springs subarea is believed to be supported by recharge originating within the area and is limited in extent. The cold water aquifer lies above the hot water system. The degree of interconnection between the two systems is unknown.

The effect of present development upon the water resources in the Hot Springs subarea is difficult to determine, primarily because of the lack of long term water level or spring discharge records. Several miscellaneous measurements of the discharge of the Hot Springs indicate the result of ground-water development of the hot artesian system. The flow of Hot Springs, prior to ground-water development, was an indication of the natural discharge of the ground-water system. The development of wells changed the equilibrium of the system, which resulted in a decline in the piezometric surface until a new balance was achieved.

This lower pressure head resulted in a smaller discharge from the springs and the wells. This downward trend will continue if more ground water is discharged by additional well development. Data are not presently available to determine the economic limit of ground-water development of the hot artesian aquifer system. The flow of Latty Hot Springs has not been altered by ground-water development. Because the Mountain Home Irrigation District well in sec. 11, T. 2 S., R. 6 E., has not been test pumped or operated, the effect of this development on the ground-water system is unknown. The cold water aquifer system in the area has not been developed to an appreciable extent; none of these wells have reported water level declines or losses in discharges.

Mountain Home subarea

The Mountain Home subarea includes the area of high water levels near the City of Mountain Home. The southern boundary of the subarea is the approximate limit of shallow (less than 300 feet) well development. The subarea is bounded on the north by the estimated southern limit of the occurrence of hot artesian water, on the west by Canyon Creek, and on the east by an arbitrary line marking an abrupt change in thickness of the Glenns Ferry Formation (fig. 5). The aquifer system in this area is important as a source of domestic and irrigation water.

The precipitation rate for the subarea, recorded at the Mountain Home Weather Bureau station, is 8.78 inches per year. Two streams, Canyon Creek and Rattlesnake Creek, comprise the surface drainage in the area. Most of the flow of these streams is diverted into the Mountain Home Reservoir. Any flow past this diversion sinks and recharges to the ground-water system. Several small springs also are located in the subarea, but do not yield enough flow to be of importance.

Four major sources of recharge to the ground-water system exist within the Mountain Home subarea: precipitation, streamflow, irrigation seepage, and sewage effluent. Some recharge is derived from Canyon and Rattlesnake Creeks and the Miller, Feeder, and East Side Canals of the Mountain Home Irrigation District. A significant quantity of ground-water recharge is derived from irrigation seepage from water applied near the city. The City of Mountain Home sewage disposal ponds recharge an undetermined quantity of water into the ground-water system. Part of the precipitation also contributes to ground-water recharge because of the limited drainage and high water table. The total quantity of water recharged to the system from the four sources is unknown.

The aquifer system in the Mountain Home subarea has been developed extensively by both domestic and irrigation wells. The wells range in depth from 10 to 600 feet. The locations of a portion of these wells are presented in Figure 7, with the well depth and the depth to water noted.

Ground water is derived in the subarea from the basalts and sediments of the Bruneau Formation. The water levels are anomalous primarily because of the existence of a number of clay beds of low permeability. In sec. 23, T. 3 S., R. 6 E., the water is perched above a clay bed present on the top of the basalt causing the shallow wells located in this area to have a high water level. In other locations, such as sec. 26, T. 3 S., R. 6 E., clay lenses are found at several depths causing the elevation of the water level to vary with the depth of the well. Because

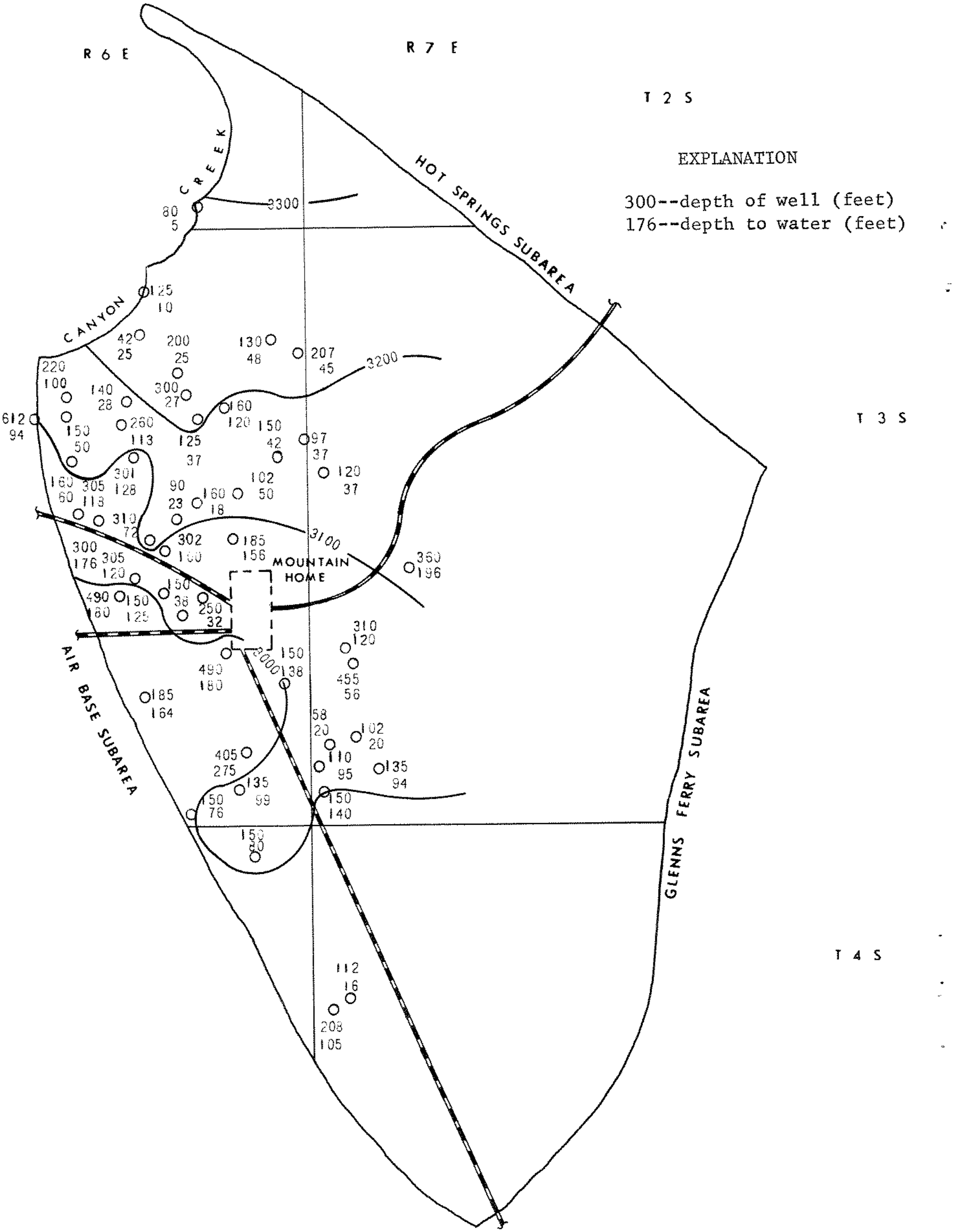


Figure 7.--Contours of water level elevation for the Mountain Home subarea and the depth, location, and depth to water of most of the wells

the basalts of the Bruneau Formation consist of a series of discontinuous flows which are generally more permeable at the top and bottom than in the center, the elevation of the piezometric level varies with depth within the basalts. The geologic cross-sections presented in Figure 4 show the abrupt changes of the water surface within the subarea. The major percentage of the ground-water flow is believed to be downward, supplying the lower aquifer system.

Contours of equal water level elevation for the Mountain Home subarea (fig. 7) indicate flow from the north to the south with a definite lessening of gradient as the flow nears the edge of the system. The yield to wells varies greatly over the subarea; a few irrigation wells have high yields with low drawdowns (high specific capacity). The present well development in the subarea has not apprecibly affected the ground-water system; significant declines in water levels or pump discharges have not been reported.

Air Base subarea

The Air Base subarea consists of the general ground-water system south and west of the city of Mountain Home near the Mountain Home Air Force Base. The eastern boundary of the subarea is defined by the abrupt change in thickness of the sediments of the Glenns Ferry Formation. The southern and western boundaries are the Snake River and Canyon Creek. The northern boundary is the northern extent of deep well development which has a water level elevation of approximately 2,700 feet. The subarea includes the deep well development within the city of Mountain Home and partially underlies the previously described Mountain Home subarea (fig. 5).

This subarea is important as a major source of ground water for irrigation in the study area.

A precipitation rate of 8 inches per year is estimated for the subarea from data available at Mountain Home and Grandview. The surface runoff is limited to flow down the many gulches and canyons after periods of precipitation. The two main drainages in the area, Canyon and Rattlesnake Creeks, are dry during the majority of the year.

Two large springs occur in the subarea, both in the canyon of the Snake River. Halls Ferry Springs, located in sec. 14, T. 5 S., R. 5 E., approximately 50 feet above the level in C. J. Strike Reservoir, discharge approximately 800 gpm at a temperature of 66° F. A chemical analysis of the spring water is presented in a later section. The springs issue from slope wash along the Snake River, and are believed to be discharge from the Bruneau Formation. The second major springs in the subarea, Weatherby Springs, in sec. 17, T. 5 S., R. 5 E., issue near the level of the Strike Reservoir and are also believed to be discharge from the Bruneau Formation. Both springs were in existence prior to the completion of C. J. Strike Dam.

The ground-water recharge in the Air Base subarea is limited because of the low precipitation rate and the deep static water level. Some recharge is believed to result from irrigation in the area. This irrigation has not continued for a sufficient period of time for the recharge effect to be noted either as a water level rise in the main aquifer or as a new perched zone.

Approximately 50 irrigation, municipal, and domestic wells have been constructed in the Air Base subarea. The locations of most of the wells are shown in Figure 8, with the depth of the well and the depth to water noted for each installation. The City of Mountain Home derives its entire water supply from seven deep wells drilled within the northern portion of the Air Base subarea.

A number of irrigation and domestic wells tap the general ground-water system south and east of the city. These wells range in depth from 400 to 900 feet. A well in sec. 35, T. 3 S., R. 6 E., (Brueck) was operated as an observation well during a portion of 1967. This water level record, presented in Figure 9, indicates very little variation. The wells in this area derive water primarily from the basalts of the Bruneau Formation.

The Mountain Home Air Force Base obtains its water supply from six wells tapping the general ground-water system. The average discharge of the air base wells is 2,231,000 gallons per day (Williams - Personel Communication - 1967). Drillers' reports indicate the water was encountered in the basalts of the Bruneau Formation approximately 360 to 400 feet below land surface, which rose to a level of approximately 330 feet below land surface.

The remainder of the wells in the Air Base subarea have been drilled to irrigate the desert lands. Significant additional well drilling and land reclamation is taking place at the present time. To date, twenty-eight wells are included in this development, most of which have been drilled since 1964. These wells range in depth from 380 to 700 feet with an average water level elevation of 2,700 feet. The drillers' reports indicate that the water is derived from the basalt and sand interbeds of the

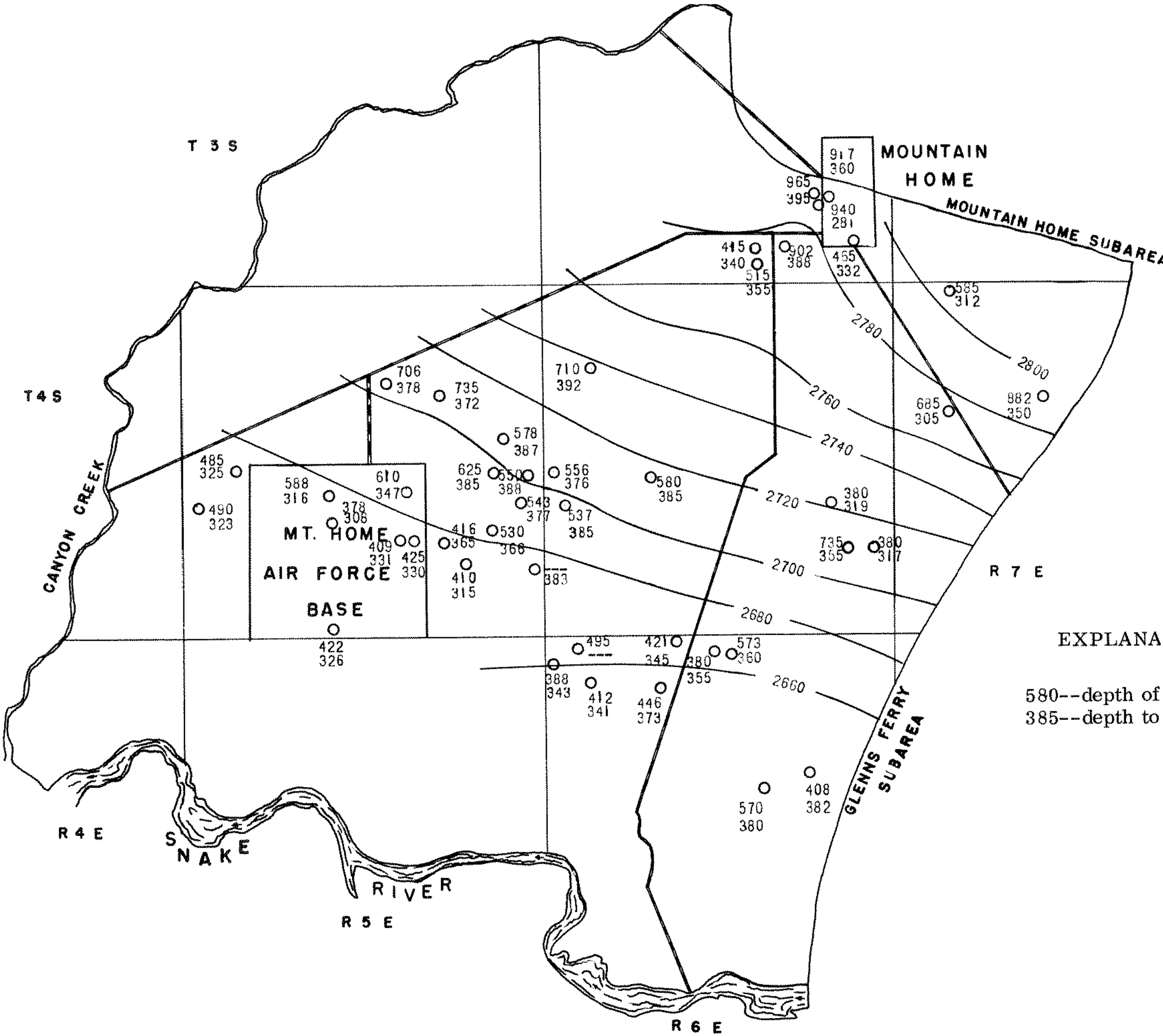


Figure 8.--Contours of water level elevation for the Air Base subarea and the location, depth, and depth to water of most of the wells

EXPLANATION

580--depth of well (feet)
385--depth to water (feet)

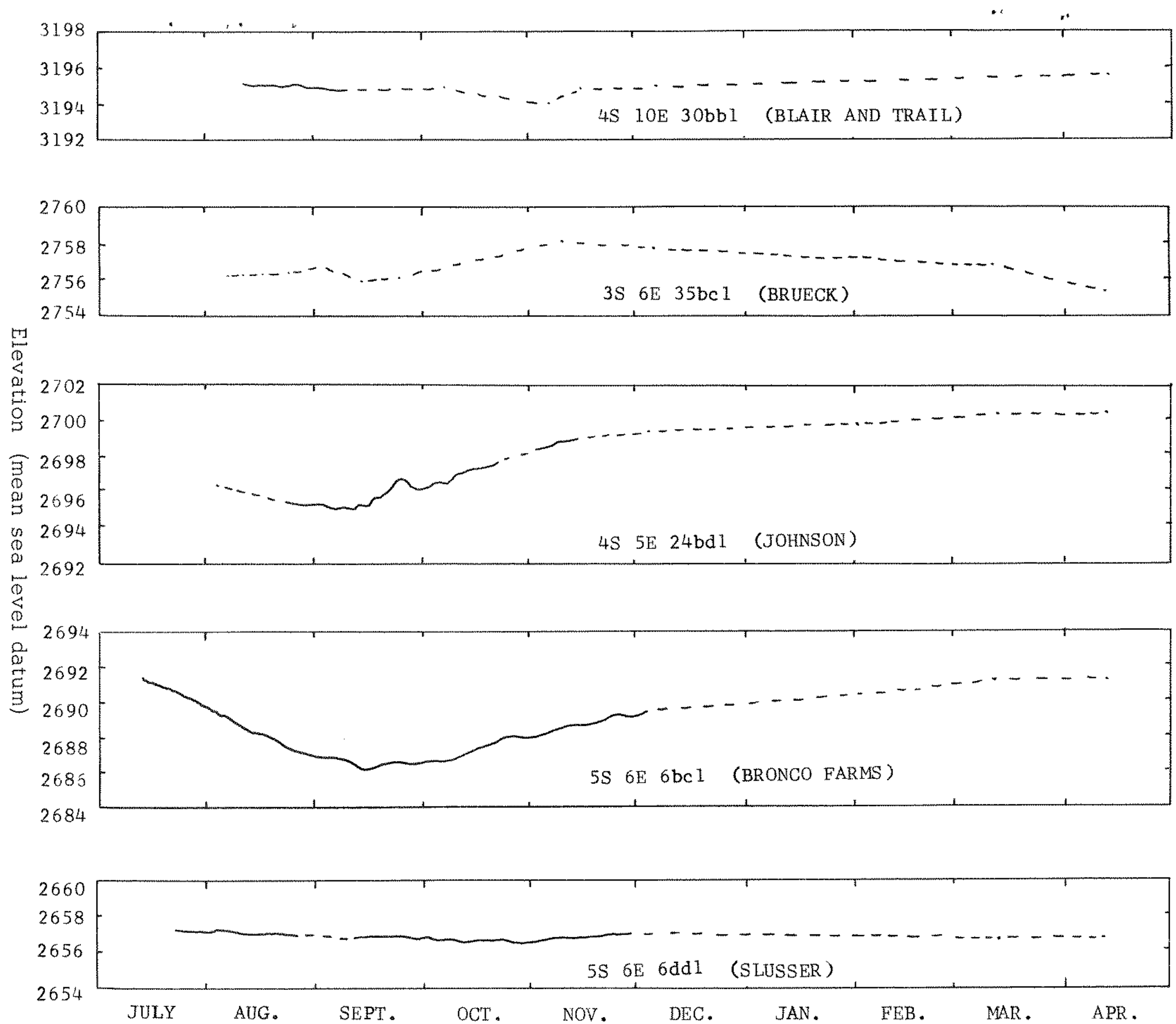


Figure 9.--Hydrographs of observation wells

Bruneau Formation. Most of the wells intersect sand beds approximately 400 feet below land surface. Several wells east of the Air Base do not encounter these sands and have a water level elevation approximately 40 feet above the general ground-water level. The yields from wells in the desert land development are generally high; specific capacities of 150 gpm per foot of drawdown are common.

Three unused irrigation wells near the air base were used as observation wells for the summer period of 1967 with miscellaneous measurements obtained during early 1968. The well in sec. 24, T. 4 S., R. 5 E. (Johnson), and the well in sec. 6, T. 5 S., R. 6 E. (Slusser) are typical of the general ground-water system. The well in sec. 6, T. 5 S., R. 6 E. (Bronco Farms), represents the higher water level previously noted. The water level record for the wells, presented in Figure 9, shows that the Slusser well in sec. 6 has the smallest change over the period of record. The Johnson well in sec. 24 shows a distinct variation with the pumpage in the area with a significant recovery. The Bronco Farms well in sec. 6 had a decline of 5 feet from the 15th of July to the 15th of September, the largest change in the area.

The water temperatures are relatively uniform throughout the Air Base subarea, ranging from about 70 to 75° F. The chemical analysis of six samples obtained from wells in the subarea also indicate uniformity.

A mass water level measurement was conducted during September 1967 to determine water level elevations in the study area. Particular emphasis was placed on the Air Base subarea. These data, coupled with miscellaneous well measurements obtained in 1966 and 1967 and a few reported water levels, were compiled to construct a contour map of water level elevation. The contours of water level elevation presented in Figure 8 indicate a gradient of approximately 10 feet per mile to the south with a range in elevation from 2,650 to 2,750 feet. This flat gradient indicates a high aquifer transmissibility and/or damming of the aquifer system near the Snake River canyon. The diagrammatic cross section presented as Figure 10 describes a geologic condition under which the damming could occur. Malde, et al (1963) indicates the elevation of the top of the Glenns Ferry Formation adjacent to the Snake River at 2,625 feet, with the overlying basalts of the Bruneau Formation from 2,625 to 2,925 feet, the sediments of the Bruneau Formation from 2,925 to 3,000 feet, and the Snake River basalts from 3,000 feet to the land surface. Several of the Air Base wells, approximately 5 miles from the river, extend to elevations of 2,400 feet without intersecting what is believed to be the Glenns Ferry Formation. The difference in elevation of the Glenns Ferry Formation between the river and the air base could be the result of either a regional northward slope of the erosion surface or by a basalt filled canyon in the Glenns Ferry Formation near the air base. The higher elevation of the Glenns Ferry Formation at the river, with its typical low permeable sediments, could form a ground-water barrier. Halls Ferry Springs thus would be a part of the overflow discharge from the aquifer system. The two facts that support the damming consideration are the existence of a very flat ground-water gradient, and the intersection of the extrapolated water table with the Snake River canyon approximately 100 feet above the level of the C. J. Strike Reservoir and almost 180 feet above

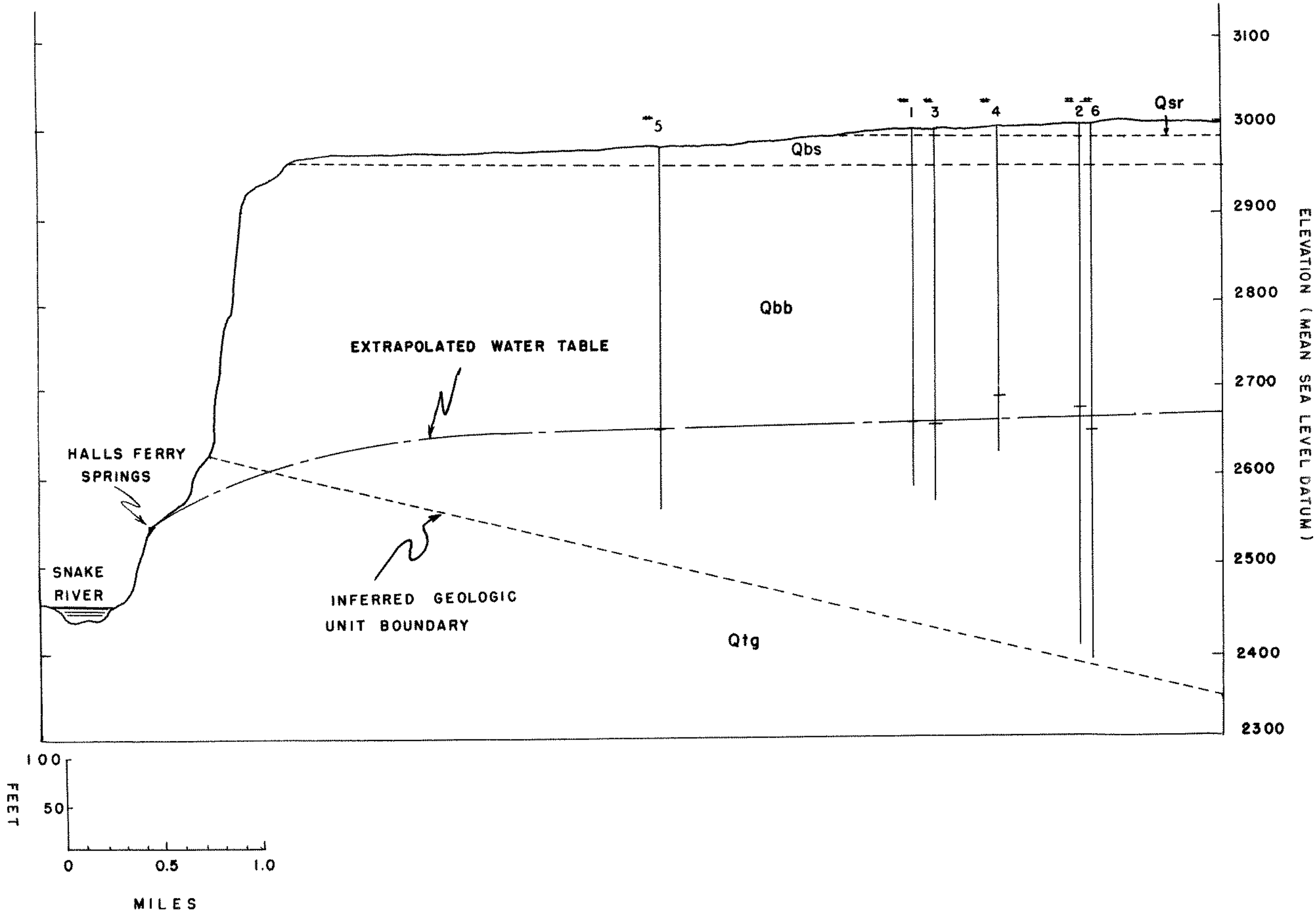


Figure 10.--Diagrammatic cross section from the Snake River to Mountain Home A.F.B.

the natural channel. Without additional data, the damming hypothesis cannot be verified.

The effect of present pumping conditions on the ground-water resources in the Air Base subarea cannot be determined because of the lack of long term water-level records. The two oldest installations in the subarea, the City of Mountain Home and the Mountain Home Air Force Base, have not kept sufficient records to determine any long term water-level fluctuations. The observation wells in the area operated by the U. S Geological Survey indicate a 2-foot water-level decline from April of 1967 to March of 1968. Without additional record, it is impossible to determine the character of the long term water level fluctuations in the area.

Glenns Ferry subarea

The Glenns Ferry subarea includes the general occurrence of warm water north of the Snake River near the towns of Hammett and Glenns Ferry. The northern boundary of the subarea is the approximate limit of hot artesian ground water from R. 7 E., to 9 E., and the front of the Mt. Bennett Hills from R. 10 E., to 11 E. The west boundary is denoted by the abrupt change in thickness of the Glenns Ferry Formation. The south and east boundaries of the subarea are the Snake River and King Hill Creek (fig. 5). This area is important as the source of warm water for low yield domestic and irrigation wells.

The precipitation rate for the subarea is estimated from the rates at Mountain Home and Glenns Ferry to be 8.8 inches per year. The streams in the subarea include Bennett Creek, Alkali Creek, Cold Springs

Creek, Little Canyon Creek and King Hill Creek. These streams all have their headwaters in the Mt. Bennett Hills. A portion of their flow is usually lost to ground-water recharge in the higher portions of the Glenns Ferry subarea, but is gained back in part from seepage as the streams approach the Snake River. Most of the lower portions of the streams flow continuously through the summer months because of seepage or discharge from the aquifer system. An undetermined portion of this seepage is return flow from irrigation in the area.

A number of small springs exist in the Glenns Ferry subarea. Three of the springs are located at approximately 2800 feet elevation. Simpkin Springs, in sec. 14, T. 5 S., R. 8 E., have a temperature of 68° F. and a discharge of about 1 gpm. Commerford Springs, in sec. 9, T. 5 S., R. 8 E., have a temperature of 64° F. and 2 gpm discharge. Both springs are perennial, issue near the top of the exposed Glenns Ferry Formation, and act as discharge points for the overlying basalts of the Bruneau Formation. Rattlesnake Springs, in sec. 16, T. 5 S., R. 6 E., issue from the sediments of the Bruneau Formation beneath the Snake River basalts. A number of other springs exist along King Hill Creek, in the eastern portion of the subarea. The extent and importance of these springs was not determined. A number of warm and cold springs and seeps have been reported along the Snake River by residents in the area.

The ground-water recharge within the Glenns Ferry subarea is believed to be small. The primary sources for recharge are streamflow, irrigation seepage and precipitation. The recharge from streamflow is believed to supply only a shallow cold water aquifer, and not reach the more general warm water system. Recharge from the limited irrigation in the area and from precipitation is also believed to be small.

The ground-water resource in the Glenns Ferry subarea has been developed to an appreciable extent only along the Snake River. A few wells exist at scattered locations in the remainder of the area. The location of most of the wells are shown in Figure 11, with the depth of the well, depth to water and water temperature presented.

Four deep wells have been drilled in the northern portion of the Glenns Ferry subarea, none of which were successful. An irrigation well, 2,265 feet deep, was drilled in sec. 30, T. 4 S., R. 10 E. Clay, silt, sand and some thin basalt flows were encountered in the well, with very hard rock present for the last 100 feet. The clay, silt and sand beds are part of the Glenns Ferry Formation; the hard rock has been identified as the Banbury Basalt. The well has a yield of only 450 gpm and a static depth-to-water of 260 feet. It was operated as an observation well through a portion of 1967. The water level record, shown in Figure 9, indicates minor water-level fluctuations throughout the summer months.

The second deep well was drilled in sec. 36, T. 4 S., R. 8 E., for Pacific Northwest Pipeline Corporation to a depth of 1,910 feet. The drillers' report indicates primarily clay, silt, and sand from 78 feet to the bottom of the hole, identified as the Glenns Ferry Formation. This well yields 6 to 7 gpm and has a static water level of approximately 400 feet. The well encountered water-bearing strata only at 25 feet and 400 feet.

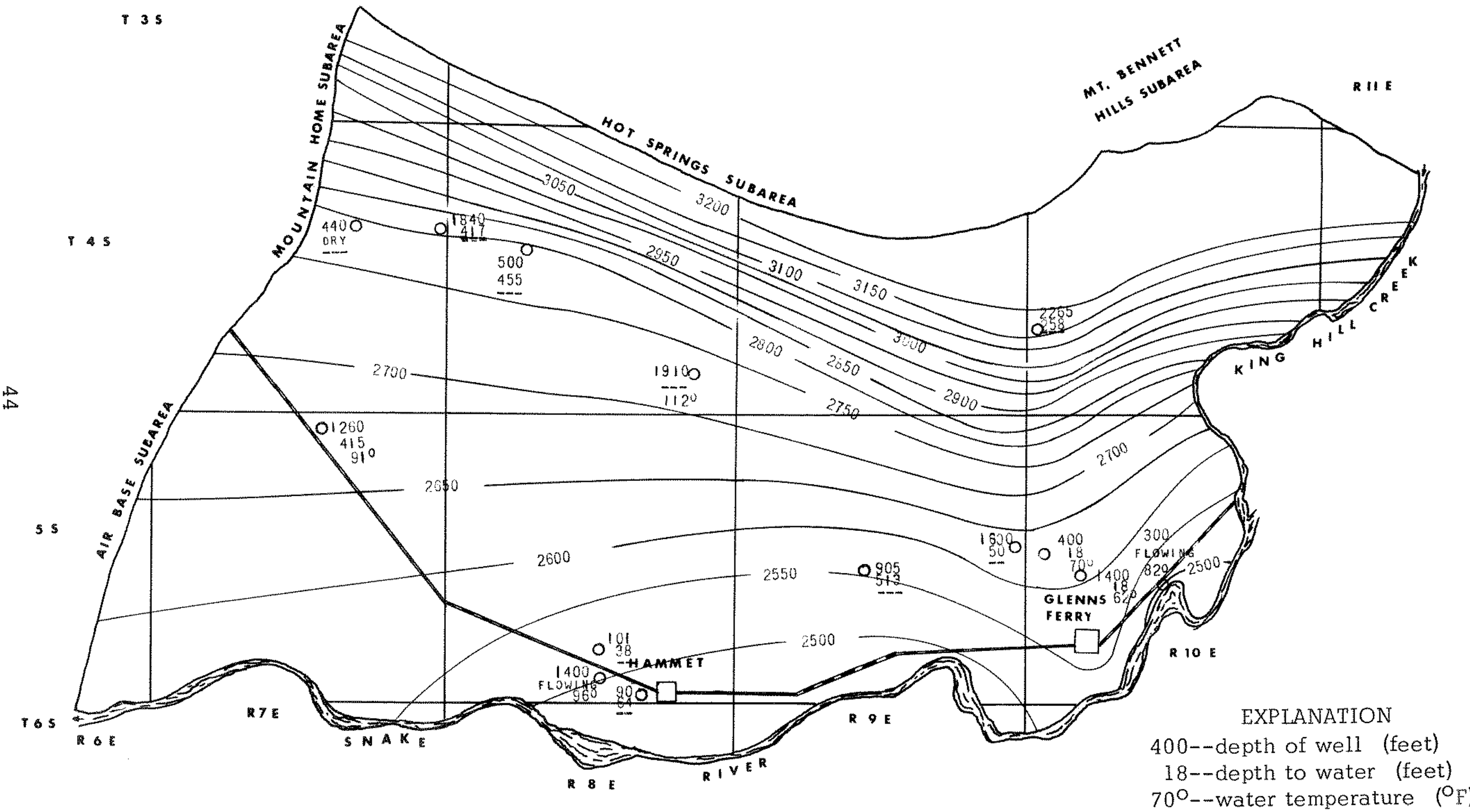


Figure 11.--Contours of water level elevation for the Glenns Ferry subarea and the location, depth, depth to water, and water temperature of most of the wells

The third deep well, in sec. 13, T. 4 S., R. 7 E., is 1,840 feet deep and intended for irrigation purposes. It has intersected approximately 703 feet of the Bruneau Formation and approximately 1,137 feet of the Glenns Ferry Formation. The depth-to-water is presently 417 feet with an estimated temperature of 120-130° F. The yield of this well is expected to be low.

The fourth deep well, in sec. 3, T. 5 S., R. 7 E., is 1,210 feet deep with a depth-to-water of 410 feet and a low yield. The drillers' log indicates clay, silt, and sand identified as the Glenns Ferry Formation from approximately 120 feet to the bottom of the well.

The wells along the Snake River in the Glenns Ferry subarea range in depth from 10 to 1,440 feet. The deep wells tap the general warm water aquifer system (70-100°) while the shallow wells tap the cold water aquifer. All of the materials encountered in the wells were clay, silt, and sand of the Glenns Ferry Formation. The well yields in this area are generally very low.

The contours of water level elevation for the warm water system in the subarea, presented in Figure 11, indicate a fairly steep ground-water gradient toward the Snake River. The elevation of the river in this reach ranges from 2,460 to 2,480 feet. The contours thus indicate the aquifer discharges into the river. The shallow cold water system in the area has a water level elevation near that of the warm system, also indicating discharge into the river.

Interrelationship of Subareas

The five subareas described in the previous section are hydrologically interrelated. The data useful in discussion of these interrelationships are variations in water level elevation and changes in ground-water quality. Contours of water level elevation are useful in determining the direction of flow and the general permeability of the aquifer system. Changes in ground-water quality are valuable in determining the effect of flow through different types of aquifer materials and the extent of mixing of the water from each of the systems.

Water Level Elevations

A generalized contour map of the elevation of the water surface is presented in Figure 12. The flow lines, perpendicular to the contours, indicate flow from the Mt. Bennett Hills south to the Snake River. The characteristics of the flow from the Mt. Bennett Hills to the Hot Springs subarea are difficult to define because of the lack of ground-water development. Discharge from the Hot Spring subarea to the Mountain Home subarea is also difficult to determine because of the absence of ground-water data. The semipervious zones indicated in Figure 12 are believed to be the result of feeder dikes to shield volcanos. The effectiveness of these dikes as ground-water barriers has not been determined, but wells constructed in the shield areas have generally been unproductive. If the vent areas are effective ground-water barriers, the flow indicated in Figure 12 is controlled by the narrow gap between the shield volcano areas in T. 3 S., R. 6 E., and T. 4 S., R. 7 E. The high ground-water gradient between the Mt. Bennett Hills and Mountain Home in the gap area might thus be the result of the narrow discharge point. Discharge from the Hot Springs subarea to the Glenns Ferry subarea is

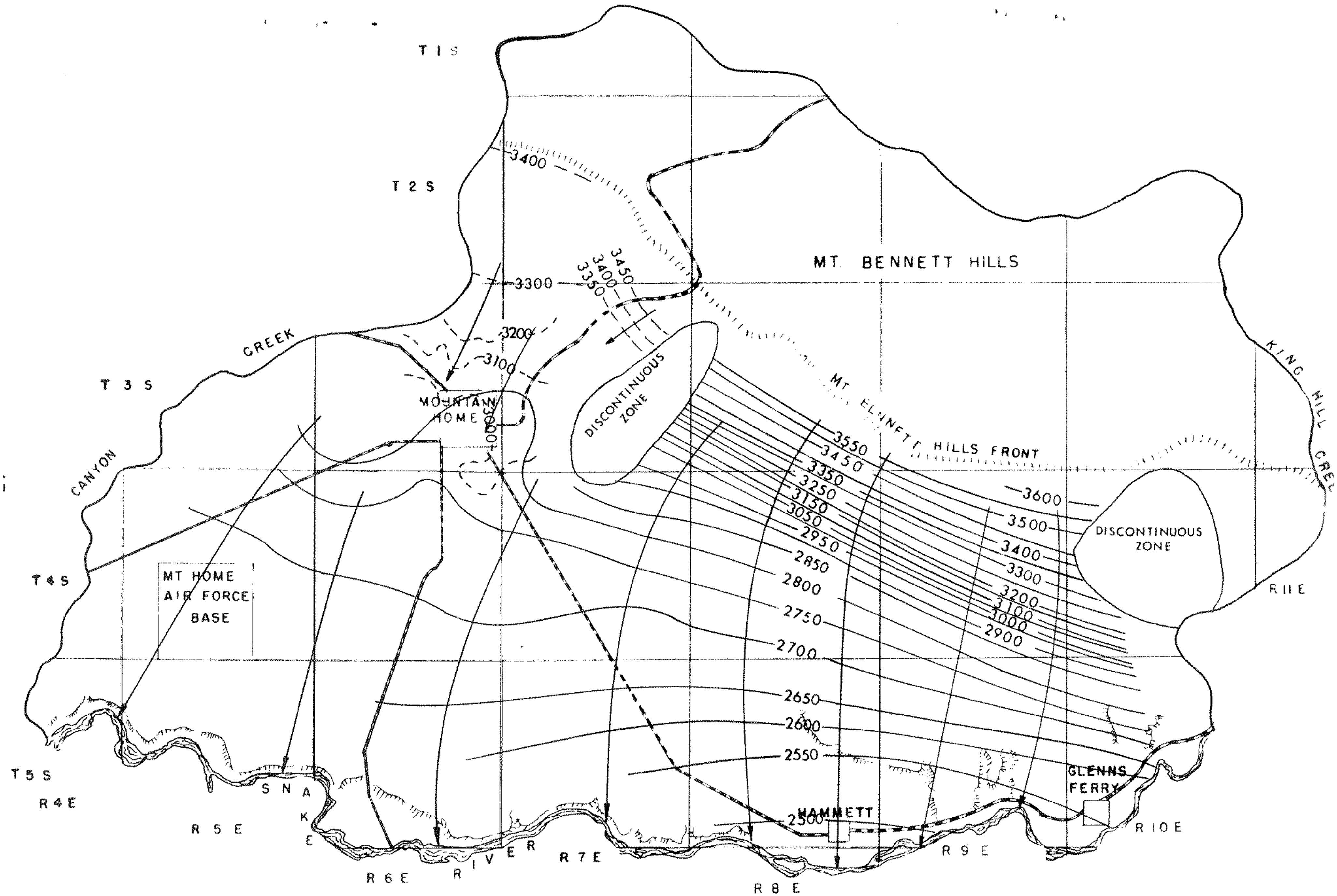


Figure 12.--Contours of water level elevation for the Mountain Home study area

characterized by a steep ground-water gradient. In the absence of a flow constriction, the steep gradient indicates an aquifer of low permeability. This supposition is supported by the fine grained character of the Glenns Ferry Formation. The ground-water discharge from the Hot Springs subarea to the Glenns Ferry subarea is unknown. The rate of ground-water movement is believed to be very slow. The flow from the Mountain Home subarea to the Air Base subarea is characterized by an overlapping of ground-water contours. This overlap supports the supposition of vertical flow from the upper Mountain Home system to the lower Air Base system. The total quantity of water transferred between the systems has not been determined. The discharge from the Air Base subarea is believed to be directed to the Snake River. The only evidence of this discharge is the spring lines at Weatherby and Halls Ferry Springs. A small portion of the flow is also discharged to the Glenns Ferry Formation. The discharge characteristics are not completely understood because of absence of data. The Snake River is believed to be the primary discharge line for the Glenns Ferry subarea. The contours of water-level elevation approach the elevation of the river indicating that discharge is to the river channel.

The water-level contours indicate that the Mt. Bennett Hills are the primary source areas for ground-water recharge for the entire study area, and that the majority of the discharge is into the Snake River. The highly permeable Bruneau Formation is characterized by a low ground-water gradient in the western portion of the study area; the less permeable Glenns Ferry Formation in the eastern portion has a high gradient. The water-level elevations indicate that the two systems are hydrologically interconnected.

Ground-Water Quality

Water from 26 wells and springs was analyzed for dissolved chemicals. The results of the analyses are presented in Table 2 with the sampling locations shown in Figure 13. The accuracy of the analyses are considered only fair because of the inbalance of total cations and total anions. Much of the error is believed to be in the sulfate ($SO_4^{=}$) portion of the analyses. Other errors may be caused by relatively high concentrations of ions not included in the analysis.

The water quality samples were obtained primarily from the deep wells in the various portions of the study area. Irrigation wells were sampled after continuous pumping for at least 24 hours. Domestic wells were sampled after shorter periods of no less than 15 minutes of maximum discharge.

The data presented in Table 2 may be divided into five groups: E. C. (specific electrical conductivity), pH, total cations, total anions, and SAR (sodium absorbtion ratio). The electrical conductivity of water depends on the concentration of dissolved solids in solution. E. C. data are useful in noting the areal change in dissolved solids in the ground-water system (Hem, 1959, p. 42). The western portion of the study area has a uniform low E. C. value (fig. 13). This value indicates flow through more permeable materials allowing less time for the water to absorb solids. The low E. C. is also indicative of a more resistant aquifer material allowing less solids to go into solution. These characteristics

TABLE 2

WATER QUALITY ANALYSES

	Location	Name	Depth of Well, ft.	EC (10⁻³)	pH	Ions in epm										SAR	Temperature, °F
						Cations					Anions						
						Ca	Mg	Na	K	Total Cations	HCO_3	CO_3	Cl	SO_4	Total Anions		
1.	3S 6E 13dd	Aquirre #3	580	0.15	7.85	0.63	0.54	0.66	0.01	1.84	1.69	T	0.54	0.07	2.30	0.9	71
2.	3S 6E 26ad	Mt. Home #6	940	0.12	8.25	0.65	0.46	0.50	0.08	1.69	1.46	--	0.54	0.27	2.27	0.7	74
3.	3S 7E 2ac	Ford	520	0.23	8.80	0.13	0.03	2.53	0.50	2.74	1.12	1.23	0.58	1.94	4.83	8.9	90
4.	3S 8E 36ca	Ross #1	585	0.30	9.05	0.10	0.03	3.69	0.04	3.86	2.14	1.12	0.54	0.77	4.57	15.4	101
5.	3S 8E 36ca	Ross #2	600	0.30	9.30	0.08	0.04	3.69	0.04	3.85	1.69	1.12	0.50	0.38	3.69	14.2	154
6.	4S 5E 19cc	Fisher	490	0.13	7.50	0.54	0.38	0.58	0.01	1.51	1.35	--	0.42	0.98	2.75	0.9	70
7.	4S 5E 24db	Poteet	543	0.10	7.65	0.56	0.33	0.44	0.07	1.40	1.23	--	0.58	0.91	2.72	0.6	77
8.	4S 6E 19ca	Smith	537	0.10	7.80	0.54	0.30	0.41	0.08	1.37	1.23	--	0.58	1.25	3.60	0.6	75
9.	4S 6E 25bc	Spencer	735	0.18	7.90	0.90	0.56	0.78	0.13	2.37	2.36	--	0.42	0.70	3.48	0.9	76
0.	4S 7E 9dc	Grofsema	862	0.27	7.85	0.46	1.23	1.03	0.12	3.34	2.25	--	0.88	0.98	4.11	1.0	75
1.	4S 8E 36bb	El Paso Sta. 11	1906	0.53	8.30	0.13	0.03	6.41	0.11	6.68	3.61	1.12	0.77	0.45	5.94	22.9	112
2.	4S 9E 3ba	Walker #4	---	0.15	7.75	0.56	0.45	0.54	0.09	1.64	2.14	--	0.58	0.72	3.44	0.7	57
3.	4S 9E 8ab	Walker #1	1175	0.31	9.25	0.08	0.04	3.56	0.04	3.72	1.69	1.12	0.38	1.03	4.22	15.0	150
4.	4S 9E 10bb	Walker #3	---	0.20	7.90	1.31	0.33	0.94	0.16	2.74	2.47	--	0.58	0.65	3.70	1.0	70
5.	4S 9E 10ac	Walker #2	600	0.20	7.90	1.00	0.33	0.84	0.15	2.32	2.36	--	0.58	0.60	3.54	1.0	70
6.	4S 10E 6ca	Steen	---	0.32	7.65	2.19	1.03	0.91	0.13	4.26	2.90	--	0.50	1.10	4.52	0.7	61
7.	5S 4E 14bb	Halls Ferry Spring	---	0.10	7.95	0.62	0.40	0.48	0.09	1.60	1.69	--	0.58	1.73	4.00	0.7	66
8.	5S 6E 4bb	Rhead	421	0.20	7.65	0.96	0.73	0.66	0.10	2.45	2.59	--	0.50	0.07	3.16	0.8	68
9.	5S 8E 34bc	Old Resort	---	1.15	7.85	0.05	0.01	12.38	0.43	12.87	8.55	2.47	1.93	0.21	13.16	72.9	92
0.	5S 10E 12db	King Hill Weigh Sta.	205	0.34	8.30	0.32	0.05	3.66	0.07	4.10	3.71	T	0.58	0.24	4.53	8.4	65
1.	5S 10E 18cd	Parmley	400	0.85	8.05	0.54	0.94	9.31	0.24	11.03	4.39	1.35	1.15	3.36	10.25	10.8	70
2.	5S 10E 20bb	Mills	1400	0.50	7.50	1.84	0.45	2.75	0.38	5.42	4.50	--	0.69	1.10	6.29	2.5	62
3.	5S 10E 21aa	Stevens	300	0.50	8.60	0.13	0.02	5.70	0.09	5.94	3.94	--	1.19	0.55	5.68	20.4	83
4.	5S 10E 29cc	Frazier	80	0.59	8.15	3.28	1.61	2.88	0.10	7.87	1.80	1.69	0.77	0.81	5.07	1.8	59
5.	5S 10E 32bd	Campinland	---	0.50	8.50	0.54	0.03	6.19	0.03	6.79	4.84	--	1.35	0.33	6.52	11.1	100
6.	5S 11E 7bc	Texaco-King Hill	1300	0.30	8.85	0.11	0.02	3.41	0.04	3.58	2.47	T	0.58	0.22	3.27	13.1	86

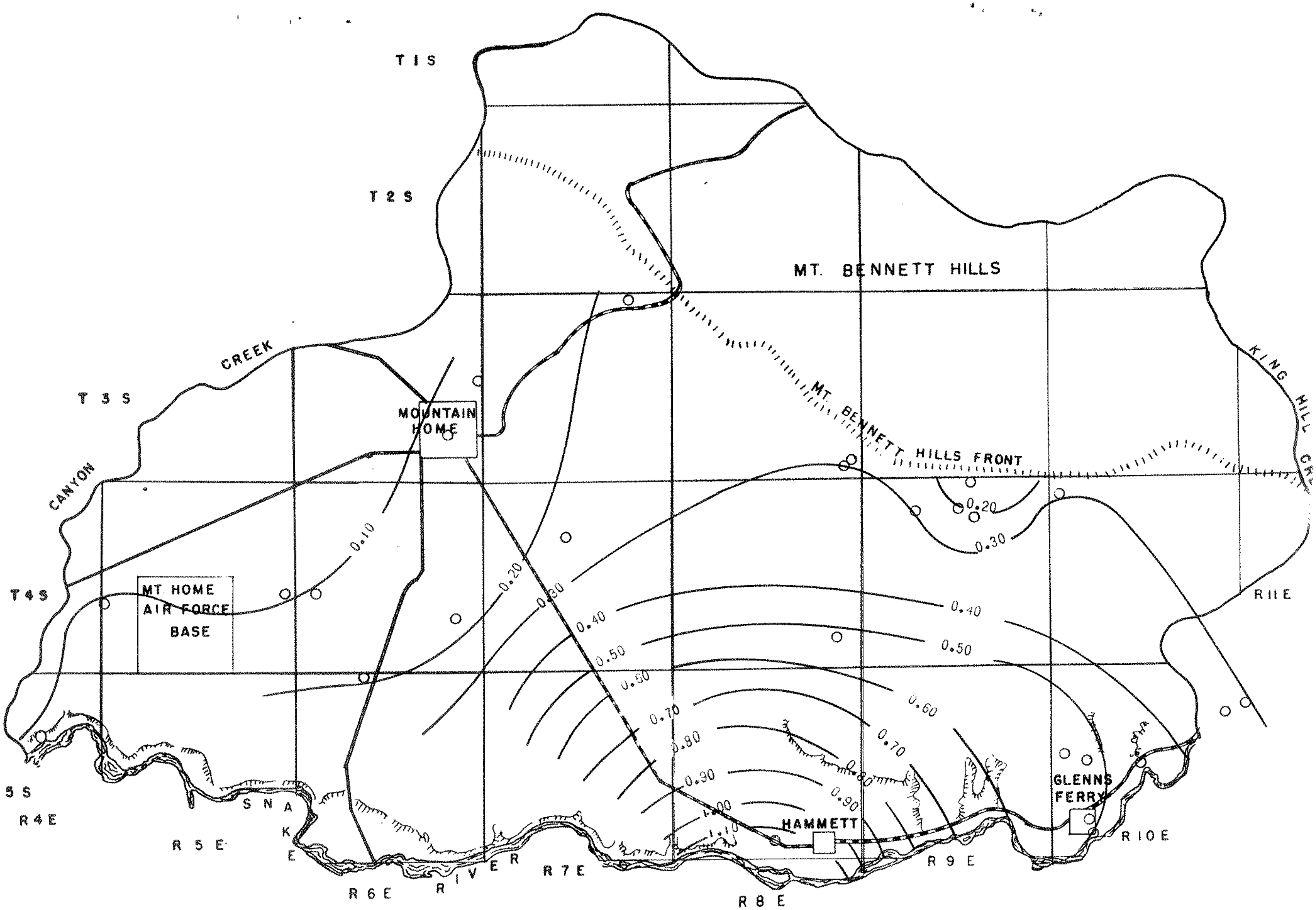


Figure 13.--Contours of specific electrical conductance (10^{-3} mhos) and locations of water quality samples

generally fit the basalts of the Bruneau Formation, the primary aquifer in the western portion of the study area. The E. C. data in the eastern portion of the study area show a change from 0.20×10^{-3} mhos in the north to 1.15×10^{-3} mhos near the Snake River. Dissolved solids are absorbed by the ground water during its flow through the subarea. The large change in dissolved solids indicates that the flow velocity is very low, and the aquifer material is not highly resistant to chemical weathering. These characteristics are typical of the Glenns Ferry Formation, the primary aquifer in the subarea. The E. C. data indicate a partial hydrologic boundary between the eastern and western portions of the study area, and show that only a small amount of mixing occurs between the systems.

The values of pH presented in the analyses are expressions of the hydrogen-ion concentration in the water samples. The pH is primarily controlled by chemical reactions and equilibria among the ions in solution and is an indicator of the chemical behavior certain solutions may have toward rock minerals (Hem, 1959, p. 44). The values of pH presented in Table 2 range from 7.65 to 9.30, all indicating basic solutions. The data from the western portion of the study area are slightly lower than those in the eastern region; the highest values are from the hot wells near the Mt. Bennett Hills.

The concentration of four cations, calcium (Ca^{++}), magnesium (Mg^{++}), sodium (Na^{+}), and potassium (K^{+}), was determined in the water analyses. Calcium and magnesium are alkaline-earth metals and contribute to the hardness of water. Sodium and potassium are alkali metals and are important constituents of natural water. The concentration of total cations in epm (equivalents per million) is important as it relates changes in all of the cations. The total cation data, presented in Table 2, are contoured in Figure 14. The contours show the same general pattern as the E. C. data presented in Figure 13; the higher total cations are in the Glenns Ferry-Hammett area.

The concentrations of four anions were determined in the quality analysis: bicarbonate (HCO_3^-), carbonate ($CO_3^=$), chloride (Cl^-), and sulfate ($SO_4^=$). The presence of bicarbonate and carbonate in solution is highly dependent on the amount of carbon dioxide that is available. Because the carbon dioxide level may change greatly during sampling and analysis, the bicarbonate and carbonate data are highly variable. Chloride is a fairly stable constituant and occurs widely in natural water. The chloride concentration varied less than any of the constituants with a contour pattern similar to that expressed by the E. C. and total cations. The sulfate data were inconsistant and impossible to interpret.

The SAR (sodium absorbtion ratio) is a ratio relating the percentages of sodium to calcium, and magnesium in epm. It is indicative of the amount of sodium absorbed by a soil irrigated with water of that specific ratio (Hem, 1959, p. 149). The SAR is used with E. C. to rate water for irrigation purposes. A plot of SAR versus E. C. (fig. 15) indicates that the ground water in the eastern portion of the area is poor to unsuitable for long term irrigation, while the water from the western portion is good to excellent.

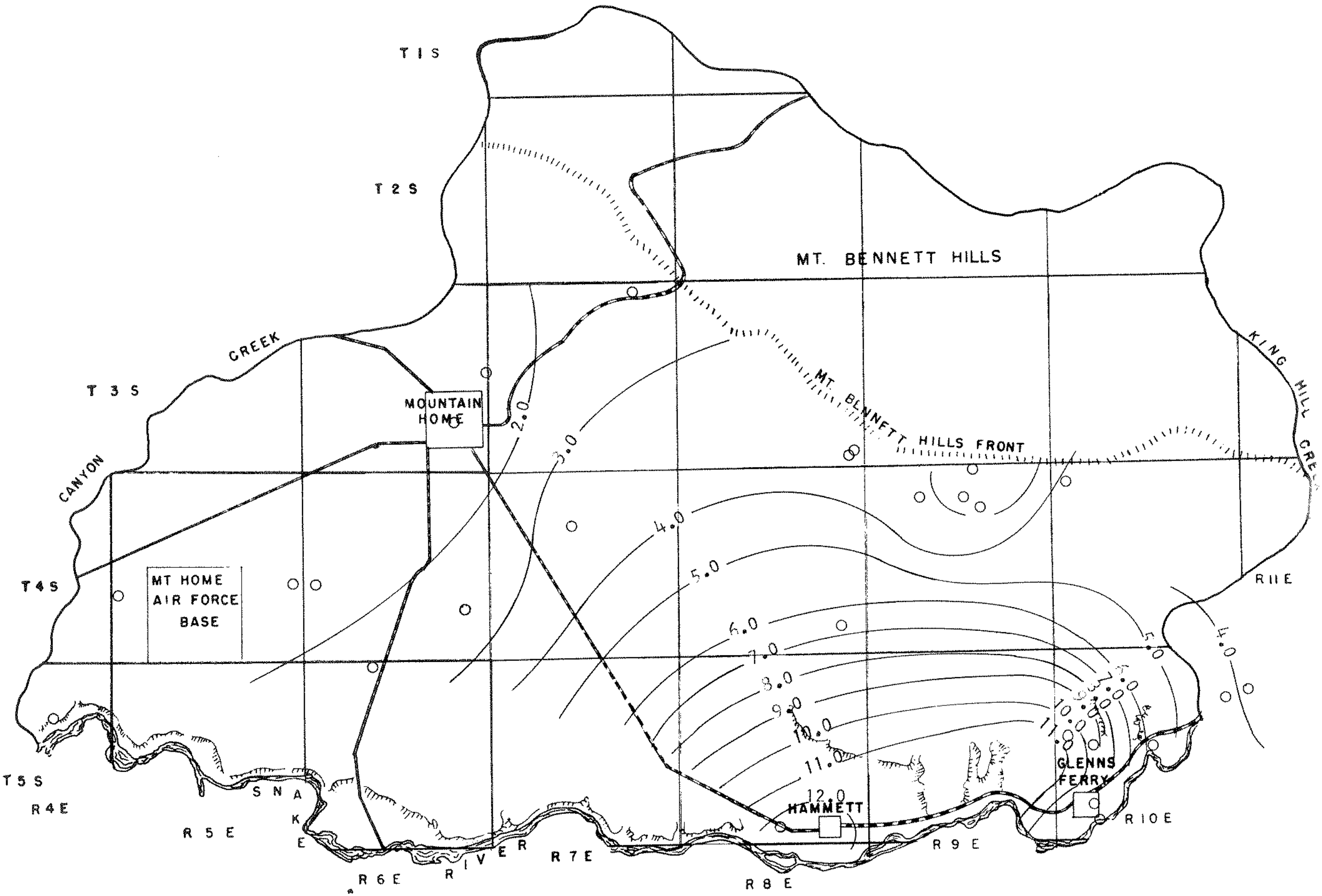


Figure 14.--Contours of total cations (epm)

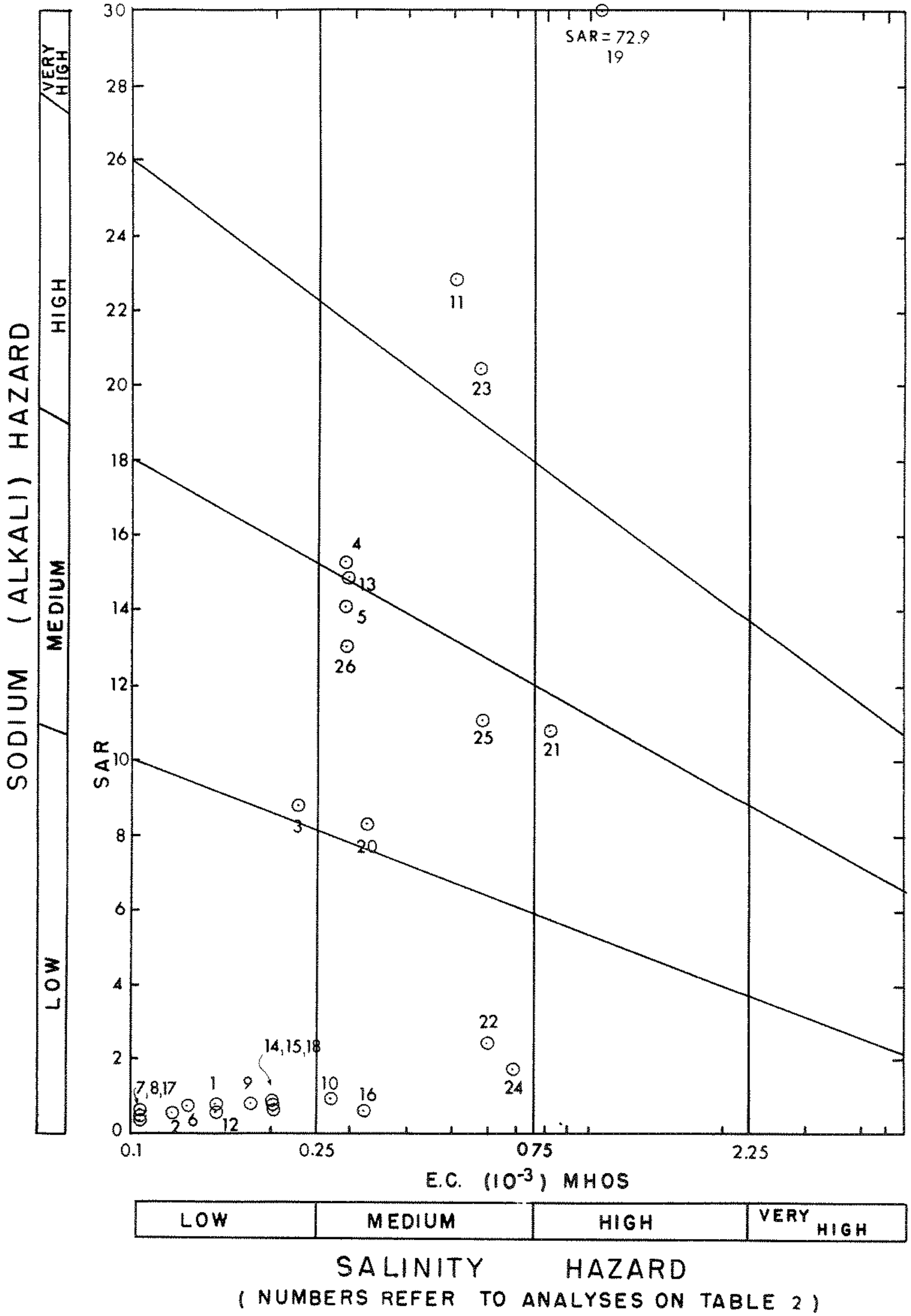


Figure 15.--Suitability of water for irrigation (SAR vs E. C.)

Availability of Ground Water to Wells

The availability of ground water to wells in the study area is shown in Figure 16 by areas of expected well yields. The areas were classified from data on well drillers' reports, records of pump tests, and general geologic and hydrologic information. The yields are divided into six catagories: 1-20 gpm, 20-100 gpm, 100-500 gpm, 500-2000 gpm, more than 2000 gpm, and unknown. The two areas of expected well yields greater than 2000 gpm are the hot artesian system in the Hot Springs subarea and a small portion of the Air Base subarea. Most of the Air Base subarea has expected well yields of 500 to 2000 gpm, with a portion rated slightly lower. Although most of the Mountain Home subarea has expected well yields of 100-500 gpm, several deep wells north of the city have high (500-2000 gpm) yields. Most of the Glenns Ferry subarea has expected well yields less than 100 gpm. Yields of less than 20 gpm are expected from the Mt. Bennett Hills subarea in the northern portion of the study area. Well yields were not estimated in three regions due to the absence of well development and ground-water data. The actual yield to wells may vary from the expected yield in any area due to variations in the efficiency of well construction and development, well diameter, and pump size and efficiency.

WATER RIGHTS

The State Reclamation Engineer has on file 125 permits or licenses for the withdrawal of ground water within the study area. The permits and licenses indicate a potential discharge of 650 cfs for both domestic and irrigation of 33,080 acres. The distribution of the ground-water

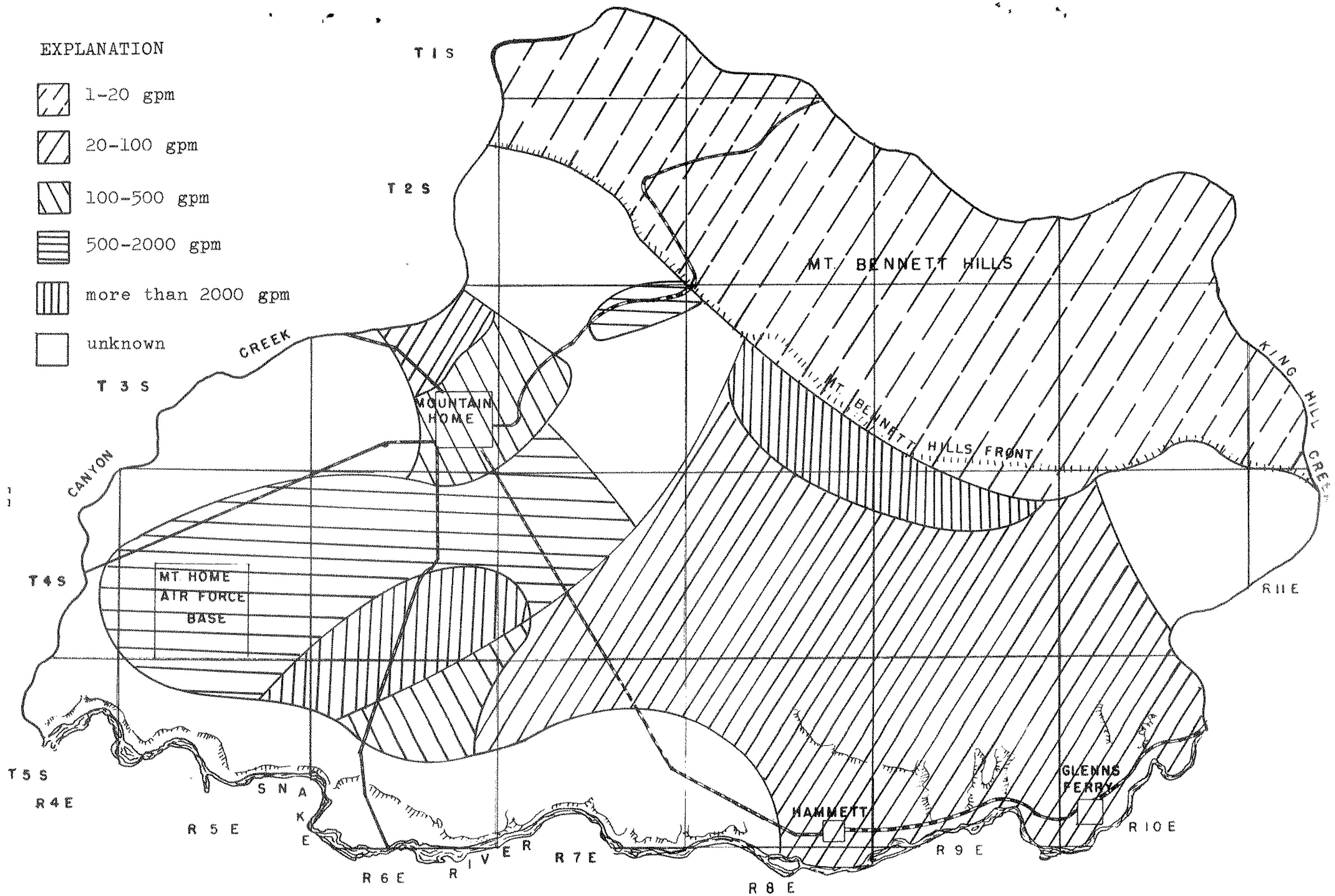


Figure 16.--Availability of ground water to wells

filings by section are shown in Figure 17. The extent of potential withdrawal is shown by denoting sections with approved discharges of 0-10 cfs, 10-20 cfs, and greater than 20 cfs. The ground-water filings are centered around the air base and the City of Mountain Home. Filings are also grouped in the area of the hot artesian aquifer near the Mt. Bennett Hills. Most of the filings in the eastern portion of the area are for small irrigation tracts and domestic uses.

The large scale development of ground water was initiated near Mountain Home in the late 1940's and early 1950's. Growth in the use of ground water in the 1950's spread from Mountain Home to isolated areas near the Mt. Bennett Hills and Glenns Ferry. New lands south and east of Mountain Home were brought under cultivation by the use of ground water in the early 1960's. The extensive development near the air base was initiated in 1963 with growth also continuing south of the city. Attempts at development were made at scattered locations during this period in the eastern portion of the area with little success. Development from 1965 to 1967 was primarily confined to the area from the air base east to U. S. Highway 30. Approximately 40 irrigation wells were drilled in the area during the period.

CONCLUSIONS AND RECOMMENDATIONS

Geology and Hydrology

The Bruneau and Glenns Ferry Formations of the Idaho Group are the primary sources of ground water in the study area. The basalts and sediments of the Bruneau Formation yield large quantities of water to

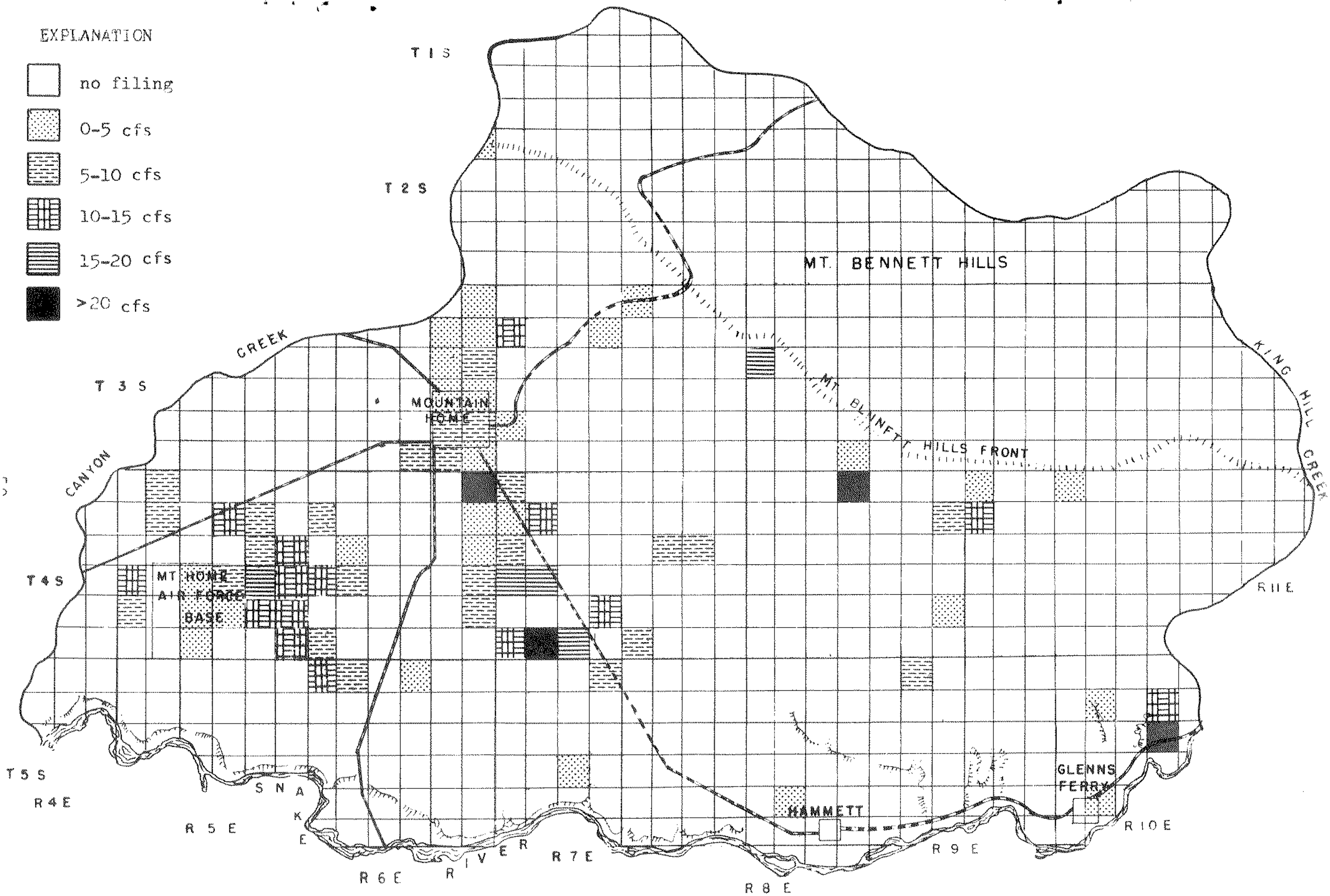


Figure 17.--Distribution of ground-water filings by section (total discharge in cfs)

wells in the western portion of the study area. The fine-grained sediments of the Glenns Ferry Formation support low yield wells in the eastern portion of the area. A system of northwest trending faults supply hot artesian water to the Glenns Ferry Formation near the Mt. Bennett Hills.

The effect of the present well development on the ground-water system in the western portion of the study area cannot be fully assessed until more records are available on the yearly fluctuations in ground-water levels. The records that are available, however, do not indicate any appreciable decline in water levels. The present and anticipated future development in the eastern portion of the study area is not expected to create any major ground-water problems. Some minor interference might occur between low yield wells near Glenns Ferry and King Hill.

The future development of the ground-water resource in the study area is expected to be located near the air base. Only a portion of the land to the west and north of the base has been developed, with no wells located between the base and the Snake River. The area north of I. S. Highway 67 is completely undeveloped and will possibly support a large ground-water withdrawal. The land south of the City of Mountain Home can also be more extensively developed. Well development will probably continue to be slow in the eastern portion of the study area because well yields are low and the water quality is considered to be fair to poor.

Water Rights

Any future proposed diversion of the hot artesian ground-water resource near the Mt. Bennett Hills should be examined with respect to the present development before being approved. The artesian system appears to have a limited rate of recharge and is very sensitive to additional discharges. The present development has resulted in an appreciable lowering of the piezometric surface. In the remainder of the study area, the present ground-water development has not been present for a sufficient period of time to indicate any water rights difficulty.

Suggestions for Future Study

A further, more extensive study of the ground-water resources of the Mountain Home area would be useful in determining more quantitative relationships between recharge, discharge, and storage. Exploratory wells in areas of no data would provide additional information. Specific localities for test holes are: 1) T. 5 S., R. 5 E., between the air base and the river, 2) T. 2 S., R. 7 E., between the Mt. Bennett Hills and Mountain Home, and 3) T. 3 S., R. 5 E., north of Highway 67. Geophysical work would be useful in determining the extent and thickness of the basalts of the Bruneau Formation and thus help define the erosional surface of the Glenns Ferry Formation. A further study of the area should also include pumping well tests to determine the aquifer coefficients. The end result of any additional study should be the determination of the safe yield value and the best use of the ground-water reservoir.

LIST OF REFERENCES

Anderson, K. E., 1966, Lee-Walker-Hall ranches ground-water study, Elmore County, Idaho: 10 p.

Dion, N. P. and Griffiths, M. L., 1967, A ground-water monitoring network for southwestern Idaho: Idaho Department of Reclamation Water Information Bull., no. 2. 16 p.

Hem, J. D., 1959, Study and interpretation of the chemical characteristics of natural water: U.S. Geol. Survey Water-Supply Paper 1473, 269 p.

Malde, H. E. and Powers, H. A., 1962, Upper Cenozoic stratigraphy of western Snake River Plain, Idaho: Geol. Soc. of America Bull., v. 73, p. 1197-1220.

Malde, H. E., Powers, H. A., and Marshall, C. H., 1963, Reconnaissance geologic map of west-central Snake River Plain, Idaho: U. S. Geol. Survey Misc. Geol. Inv. Map I-373.

Nace, R. L., West, S. W., and Mower, R. W., 1957, Feasibility of ground-water features of the alternate plan for the Mountain Home project, Idaho: U.S. Geol. Survey, Water-Supply paper 1376, 116 p.

Nelson, M. W. and Wilson, J. A., 1964, Summary of snow survey measurements for Idaho: U. S. Department of Agriculture, Soil Conservation Service, p. 78-79.

____________, 1966, Water resources data for Idaho: U.S. Geol. Survey, p. 175-176.

Plate I -- Geologic Map

Recent

Qal, Qls, Qd: Surfacial Material---unconsolidated detritus conforming to present topography.

Qal, stream alluvium
Qls, landslide debris
Qd, dune sand

Pleistocene — Upper Pleistocene — Snake River Group

Melon Gravel---boulders, cobbles, and pebbles of basalt in a matrix of basaltic sand arranged in giant cross beds. Derived from nearby outcrops of basalt. Boulders commonly 3 feet in diameter, some as large as 10 feet. Deposits rise as much as 300 feet above the Snake River.

Qsr: Basalt of Snake River Group, undivided---generally porphrytic, plagioclase-olivine basalt. Fresh, moderately rough surface.

Qc: Crowsnest Gravel---lithology variable. Gontains abundant pebbles of silicic volcanics, porphry, and quartzite. Occupies terraces from 50 feet to more than 250 feet above the Snake River.

Qsb: Sugar Bowl Gravel---pebble gravel rich in quartzite and porphry that forms a terrace deposit 25 feet thick and 400 feet above the Snake River between Pasadena Valley and Indian Cove.

Pleistocene — Lower and Middle Pleistocene — Idaho Group

Qbf, Qbs, Qbb: Bruneau Formation---canyon fill of undeformed, unconsolidated detrital material and interbedded basaltic lava flows associated with marginal deposits of gravel and basalt. Thickness of canyon filling sequences about 800 feet near Bruneau.

Qbs, detrital material dominated by massive lake beds of white-weathering fine silt, clay, and diatomite in layers 50 feet or more thick, with minor amounts of alluvial silt and sand. Includes conspicuous beds of iron-stained beach gravels.
Qbf, fan gravel, cobbly to pebbly. Deposits north of Snake River merge with lava flows and detrital material in the canyon fill.
Qbb, basaltic lava flows that erupted from several vent areas at various times to form a series of lava plateaus and dams. Lavas locally stained brown and yellow but not generally softened by decomposition.

Pliocene — Upper Pliocene — Idaho Group

QTg: Glenns Ferry Formation---basin fill of poorly consolidated detrital material. Primarily lake and stream deposits characterized by abrupt lateral changes in facies. Facies include: (1) silt in massive layers marked with faint banding, (2) sand in evenly layered thick beds cemented locally to flaggy sandstone, (3) thinly bedded dark clay, olive silt, and carbonaceous shale, (4) ripple marked sand and silt, (5) granitic sand and fine pebble gravel. With these facies are several thin beds of silicic volcanic ash and thicker beds of basaltic fragmental material. About 2,000 feet of beds exposed.

Pliocene — Middle Pliocene

Tb: Banbury Basalt---lava flows of olivine basalt interbedded locally with minor amounts of stream and lake deposits. Basalt commonly altered to greenish-brown basaltic saprolite with residual spheroids of undecomposed rock. Thickness exceeds 1,000 feet northeast of King Hill and 800 feet in the canyon of the Bruneau River.

Lower Pliocene

Tiv: Idavada Volcanics---silicic latite, chiefly thick layers of devitrified welded tuff but includes some beds of vitric tuff and lava flows. Thickness exceeds 2,000 feet in the Mt. Bennett Hills.

Kg: Granitic Rocks of the Idaho Batholith.

Contact--dashed where approximately located; short dashed where inferred.

Normal fault--dashed where approximately located; dotted where concealed Bar and ball on downthrown side.

Strike and dip of beds--barb indicates direction of dip estimated from a distance or from aerial photographs.

Sources of basaltic lava flows.